RCA Ham Tips

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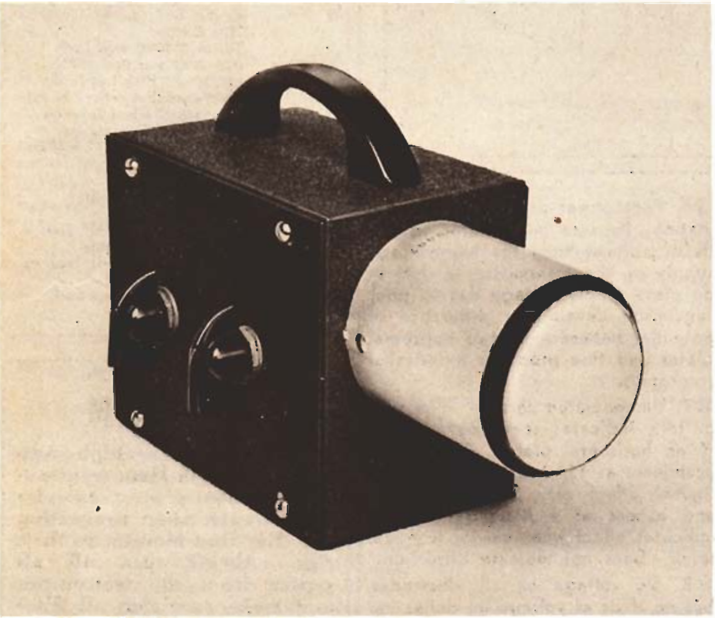
UNIQUE 'RAY GUN MONITOR CHECKS MODULATION QUALITY

'RAY GUN MONITOR



The unique unit shown above improves Ham 'phone technique by giving a positive visual indication of modulation quality. It's easy to build and can be made from a 2BP1 tube and a few inexpensive components

SIMPLE VISUAL MONITOR 'SCOPE EMPLOYS 2BP1 CATHODE-RAY TUBE

By J. H. Owens, W2FTW

If you would like to see your voice as others hear it, and if you would like to hear your station praised by those who can't see it, take this tip to check up on the quality of your modulation. It's so easy and so positive with the new RCA 'Ray-Gun Monitor.

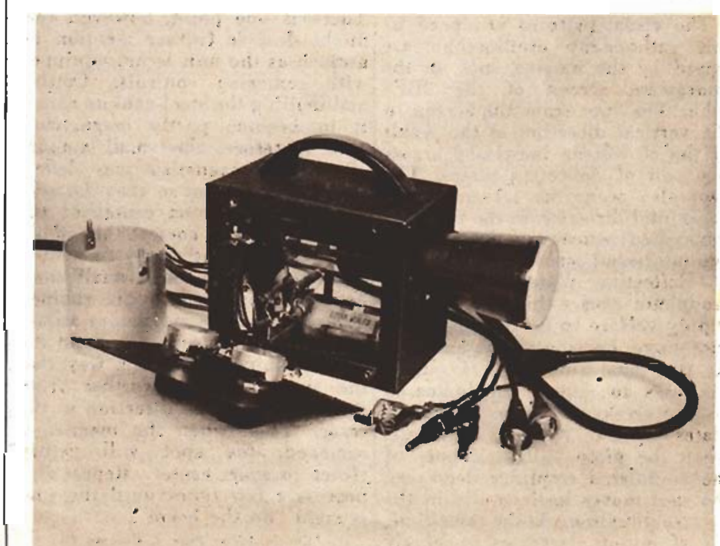
The modern Amateur phone station transmits with a modulated signal comparable to that of a broadcasting station. In common use are the techniques of high-frequency pre-emphasis, band-width restriction, correct phasing of non-linear voice waves, automatic modulation control, clipper-filters, compression, harmonics suppression, and other very professional engineering practices. Of course, such advanced practices require the use of elaborate test and measuring equipment, but a great amount of progress can be made with a simple cathode-ray visual indicator such as the 'Ray-Gun Monitor.

Consisting of an RCA-2BP1 CR tube, a 3" x 4" x 5" cabinet, an 807 tube shield, with several resistors, capacitors, and pieces of wire, the unit can be put together in a few hours by the average ingenious Amateur. Reference to the circuit diagram will prove that there are fewer complications involved than would be encountered in the building of a "one-tube blooper".

The 'Ray-Gun Monitor is built without a power supply to provide portability, simplicity, and low cost. By means of flexible clip-lead cables it can be attached readily to almost any amateur transmitter. A pair of alligator clips are used for connecting a source of 6.3 volts to the heater. If the heater supply is not grounded, make sure that the peak heater-to-cathode voltage on the 2BP1 does not exceed ±125 volts. A larger battery-clip goes to the transmitter ground, which is also the negative high-voltage return. One of the insulated pee-wee (red) clips connects to the unmodulated high-voltage dc, and the other one (black) goes to the modulated high-voltage supply of the plate-modulated final amplifier. RF is fed into the unit through the

(Continued on Page 2, Column 1)

AN INTERIOR VIEW



The 'Ray Gun Monitor with its cabinet cover removed shows a logical layout of wiring and parts. It requires no power supply.

ANALYSIS OF CLASS B MODULATORS FOR AMATEUR 'PHONE APPLICATION

Brass-pounding may provide the basic interest in Amateur Radio, but "mike hounding" gives it the flavor of romance. Radiophone communication has the charm of reality—to hear the other fellow's voice as he hears yours—to speak half-way around the globe as if in person—this is a treat the whole family can enjoy.

If you haven't as yet tried 'phone, why not give it a fling? The cost is moderate, and the benefits can be very worthwhile. For instance, putting sound on your carrier will acquaint you with subjects of interest in radio-broadcasting, public address, and the other electronic arts and professions.

Where to start? Probably you are already familiar with microphone and speech amplifier circuits. The modulator is the final link in the radiophone chain, so a review of the theory and design practice of class B amplifiers is in order.

Basic Principles

A class B audio-frequency amplifier employs a pair of tubes, connected in push-pull, and biased near the point of plate-current cutoff, where the grid-voltage—plate-current characteristic starts to bend sharply. At low signal levels both tubes work together in complementary fashion, but at higher levels each tube alternately conducts and rests, and the resulting half-waves are combined in the modulation transformer to produce a composite wave which is an amplified replica of the original signal.

Objectives

One advantage of class B operation is that it provides high peak

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'RAY GUN SCOPE VISUAL PATTERNS

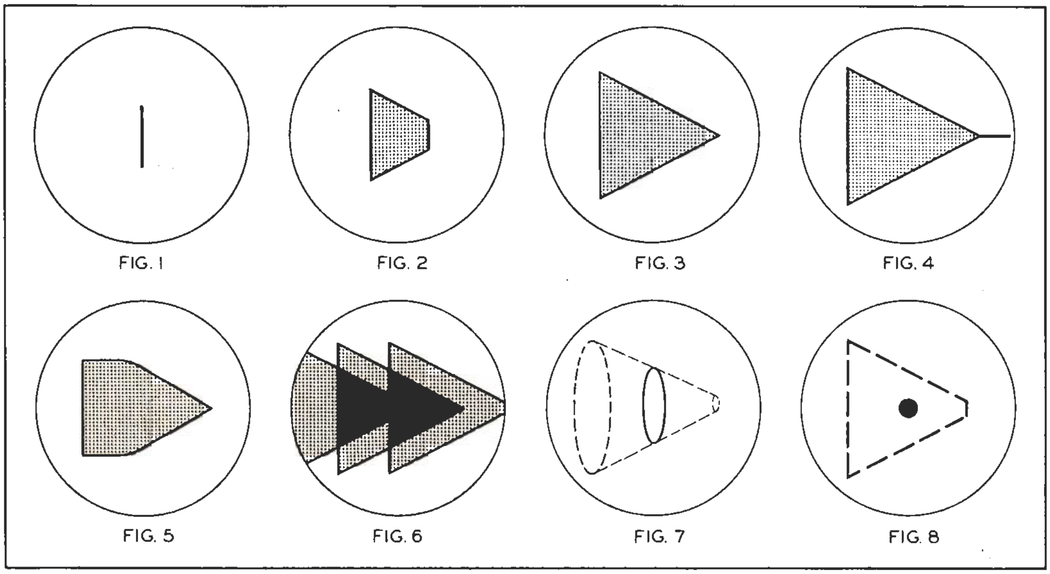


FIG. 1 FIG. 2 FIG. 3 FIG. 4 FIG. 5 FIG. 6 FIG. 7 FIG. 8

#1. Unmodulated carrier. RF on vertical-deflection plates. No ac voltage on horizontal-deflection plates. Adjust rf coupling loop so that vertical line is about one-half inch long. A thickened line indicates hum or other noise on carrier.

#2. 50% modulated carrier. Left-end vertical line is 50% longer than unmodulated line of Fig. 1. Right-end vertical line is 50% shorter than the same unmodulated vertical line. Straight diagonal lines indicate linear modulation.

#3. 100% modulated carrier. Left-end vertical line is 100% longer than unmodulated line. Right-end vertical line is 100% shorter than unmodulated vertical line. Carrier shift is present when left-end vertical line is less than twice as long as unmodulated line. If unsymmetrical speech waves are properly phased, left-end vertical line may be more than twice as high as unmodulated line, and without distortion.

#4. Overmodulated carrier. Right-end spout indicates complete disappearance of carrier on negative peaks of modulation. Bad modulation splatter results due to generation of high-frequency audio harmonics.

#5. Downward modulated carrier. Final amplifier incapable of 100% positive-peak modulation. May be due to insufficient grid drive, too much fixed bias, insufficient grid-leak bias, or low emission of final tubes.

#6. Poor power supply voltage regulation. Because the monitor obtains its dc voltage from the high-voltage supply of the transmitter, a shift in dc plate supply voltage due to poor regulation develops a difference of potential between the two horizontal plates and thus produces a series of trapezoids.

#7. Unmodulated carrier. Ellipsoidal pattern indicates some out-of-phase rf on horizontal plates. Effect is as prominent at 150 Mc as illustrated in figure. Effect very slight at 30 Mc, and absent at 4 Mc. Dashed line indicates effect when carrier is modulated. Does not indicate distortion.

#8. Dc voltage on all electrodes, but no rf or af voltage on deflecting plates. Expanded spot indicates that deflection plates are picking up some stray rf and af voltages. 100% modulation can not reduce small end of trapezoidal pattern smaller than size of spot, as indicated by dashed line.

RAY GUN MONITOR

(Continued from Page 1, Column 4)

coaxial cable from the Faraday-shield pick-up loop. One of the knobs is a brightness control and the other one is for focusing the electron beam to a tiny spot.

The visual patterns produced by this cathode-ray oscilloscope are traced by the moving spot on the fluorescent screen of the 2BP1 tube. The spot scans the screen in the vertical direction as the result of the rf voltage impressed across one pair of deflecting plates. The spot also scans the screen in the horizontal direction as the result of the audio-frequency modulator voltage impressed across the other pair of deflecting plates. When the modulator causes this class C plate supply voltage to be increased, the spot moves horizontally to one side. At the same time, the rf output increases to supply an increased voltage across the vertical deflector plates of the 2BP1. Conversely, when the plate voltage supply of the modulated amplifier decreases, the spot moves horizontally in the reverse direction. At the same time, the rf output decreases to supply a reduced voltage across the vertical-deflection plates of the 2BP1. The result is that the spot forms a trapezoid.

Construction

The utter simplicity of the 'Ray-Gun Monitor precludes a discussion of the details of fabrication. There is one point, however, that might deserve further mention inasmuch as the unit is not equipped with centering controls. Cutting and drilling the steel cabinet causes it to become partly magnetized, and, therefore, the small amount of residual magnetism may deflect the electron beam so that the spot is not in the exact center of the tube screen. To correct this condition it is only necessary to neutralize the effect of the small magnetic field produced by the cabinet. Take a horseshoe magnet, or an old PM speaker, and move it about the closed cabinet in such a way that the spot is forced further from center in the same direction as the error. Then when the magnet is removed, the spot will return closer to exact center. Repeat this process a few times until the spot is right "on the beam".

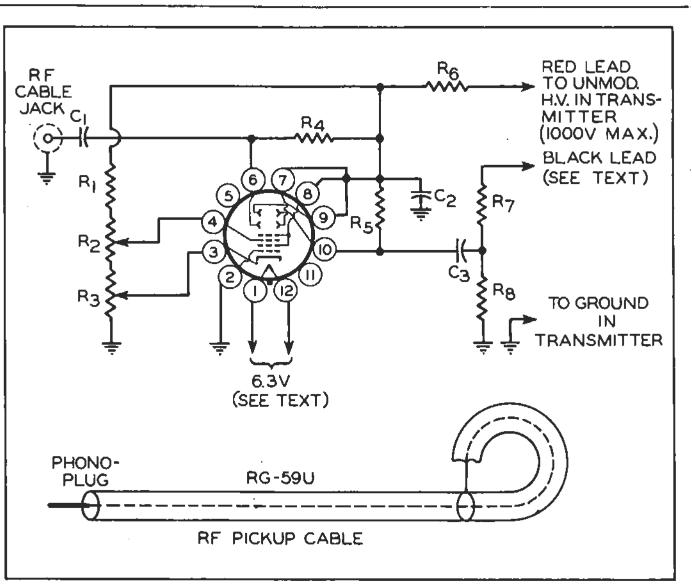
(Continued on Page 4, Column 1)

PARTS LIST

R1	1 megohm, 1 watt
R2	500,000 ohms, midget potentiometer—straight line taper preferred
R3	50,000 ohms, midget potentiometer—tone control taper preferred
R4	0.5 megohm, 1 watt
R5	3.9 megohms, 1 watt
R6	68,000 ohms, 1 watt
R7	2.2 megohms, 1 watt
R8	150,000 ohms, 1 watt
C1	0.005 µf Centralab BC-Hi-Kap or equivalent, 500 volts dc working
C2	0.1 µf paper capacitor, 1000 volts dc working
C3	0.01 µf Centralab BC-Hi-Kap or equivalent, 500 volts dc working
1	RCA 2BP1 cathode-ray tube (2")
1	Alden (Na-ald) #212FTSC diheptal socket (alternate, Amphenol #59-402-12)
1	3" x 4" x 5" metal cabinet
2	Knobs, Bud #K-575 or ICA #1125
1	Millen #80007 shield can
1	ICA #2375 or Bud #PL-247/JP-248 Plug and Jack
1	Drawer-pull or cabinet handle
2	Birnback #430 or Johnson #600 standoff insulators
2	Bud #TS-1973 or ICA #2438 terminal strips
4	Pee-Wee Clips
1	Small-size battery clip
2	Rubber clip-covers
6	Rubber grommets, ½" size
1	RG-59U coaxial cable
1 ea.	Red and black test lead cables (2 or 3 feet)
3 ea.	Pieces flexible push-back wire (2 or 3 feet)

CAUTION

Because of the high voltages present in Ham transmitters, Amateurs must exercise special care when connecting the 'Ray-Gun Monitor to their rigs. Always turn off all power from the transmitter and make sure that all filter condensers are completely discharged before making any clip lead connections. It's better to be safe than sorry!



Schematic diagram of 'Ray Gun Monitor. Connections to base pins 9 and 10 may be interchanged to reverse the pattern horizontally.

CLASS B MODULATORS

(Continued from Page 1, Column 2)

output power with respect to the no-signal input power. In the quiescent "no signal" condition, audio amplifier tubes dissipate all of the power delivered to them. As a result, if high plate voltages are used, the quiescent plate current must be kept low in order that dissipation ratings will not be exceeded under the no-signal condition.

Good plate circuit efficiency is another characteristic of class B audio amplifiers. One reason is that when the input signal level becomes appreciable, all of the plate current becomes signal plate current. Also, as a result of the grids being driven positive, the plate voltage swings all the way to the diode line on peak positive grid excursions and the peak values of plate current are, therefore, much higher than would be obtained under class A, AB, or AB_2 conditions. In the case of high-perveance tubes like RCA-811's, the voltage at the diode line is small, thus providing an efficiency factor approaching the theoretical maximum of 78.5% which would exist if the plate swing equalled the plate-supply voltage, as shown by the formula:

$$\text{Plate efficiency} = \frac{\pi}{4}\left(1 - \frac{E\,min}{E\,b}\right) 100$$

Where E min is plate voltage at diode point and E_b is the plate-supply voltage. If E min is taken as zero, the plate efficiency is equal to 78.5%.

In a practical circuit, using a pair of RCA-811's at 1500 volts and a load line of 4400 ohms (17,600 ohms plate-to-plate), the voltage at the plates (E min) would be pulled down to 70 volts on maximum signal peaks. Under these conditions, the efficiency formula would give the following results:

$$\text{Plate eff.} = \frac{\pi}{4}\left(1 - \frac{E\,min}{E\,b}\right) 100 =$$

$$0.785 \quad (1 - (70 \div 1500)) \quad 100 =$$

$$0.785 \times 0.954 \times 100 = 75\%$$

This formula holds for pure sine-wave signals only, and does not take into account transformer losses. If considerable harmonic distortion is allowed, the efficiency can be slightly higher, but such distorted power output should not be credited as useful power output. Reputable tube manufacturers indicate conservative values of tube power output from which it is only necessary to deduct transformer losses to obtain actual amplifier power output.

Typical Operation

Although tube handbooks provide tables of typical operating data, it is frequently desirable to establish a set of conditions for a particular application that has not been previously used as an example. To illustrate the procedure, consider the combination of a 1500 volt dc power supply and a pair of 811's, but the need for only 140 watts of audio power.

To be on the safe side and provide for a slightly higher than normal amount of circuit and component losses, a conservative efficiency factor of 70% should be used. The required plate power input to a class B amplifier (P_{in}) can then be determined from its relation to the desired power output (P_o):

$$P_{in} = \frac{P_o}{0.7} = 140 \div 0.7 = 200 \text{ watts}$$

The total dc plate current (I_b) at maximum signal, with a plate-supply voltage (E_b) of 1500 then becomes

$$I_b = \frac{P_{in}}{E_b} = 200 \div 1500 = 133 \text{ ma}$$

The next step is to determine the peak value of signal plate current per tube (I_p):

$$I_p = \frac{\pi I_b}{2} = 1.57 \times 133 = 210 \text{ ma}$$

Reference to the plate family will show that 210 ma is located on the diode line at approximately 50 volts. This means that the plate swings from 1500 down to 50 volts on peak positive grid excursions, and provides a peak plate swing (E_p) of 1450 volts. The load line can now be drawn as a straight line between 1500 volts at zero plate current (E_b) and the point of intersection of 210 ma (I_p) and 50 volts (E min). The load resistance (R_L) represented by this line can be calculated as follows:

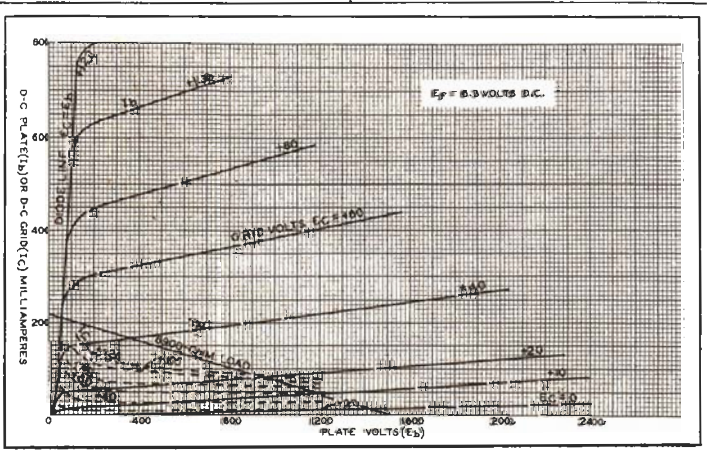
$$R_L = \frac{E_p}{I_p} = \frac{1450}{0.210} = 6900 \text{ ohms}$$

The equivalent plate-to-plate load impedance is four times the plate load per tube, or 27,600 ohms. This value of effective load resistance is optimum for the conditions set up in the problem. If a lower value is used, more power output can be obtained but the efficiency will be slightly lower. Any difference in distortion is negligible. Plate power output for a class B amplifier can now be calculated from the formula:

$$P_o = \frac{I_p\,(E_b - E\,min)}{2} =$$

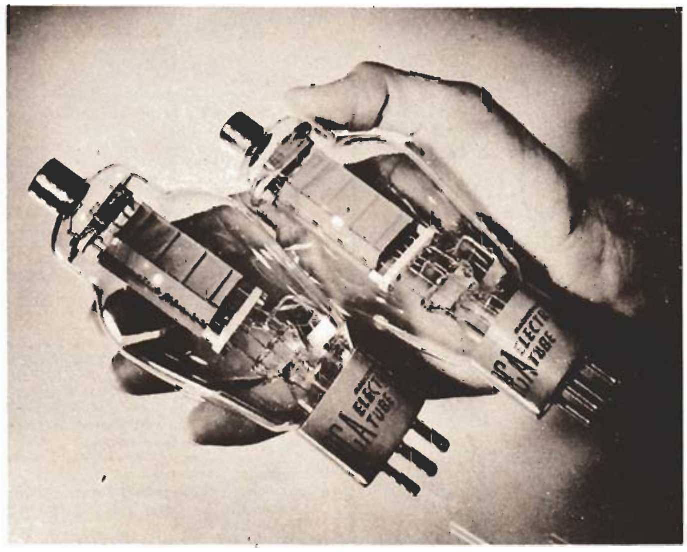
$$\frac{0.210\ (1500 - 50)}{2} = 152 \text{ watts}$$

This is more than the required 140 watts and provides ample safety factor for higher than normal circuit and component losses.



Average plate characteristics of the 811. Note that emission capabilities far exceed class B amplifier requirements.

A FAMOUS PAIR—RCA-811'S



These transmitting triodes have long been the Amateurs' favorite class B modulators.

Grid-Circuit Conditions

The exact value of negative grid bias (E_c) needed is not critical. A satisfactory approximation can be obtained by dividing the plate-supply voltage by the tubes' amplification factor. In the case of 811's, which have a mu of 160, the value obtained is —9.5 volts. This value would be exact cutoff if the grid-voltage/plate-current characteristic were a straight line. In practice, this theoretical cutoff voltage is very near to the optimum bias voltage.

At plate potentials of 1250 volts or less, the 811's will operate within plate dissipation ratings without any negative grid bias. Because of this feature, they are called "zero bias modulators". High-mu tubes can be used without negative grid bias when the product of plate voltage and quiescent plate current is less than the tubes' dissipation ratings.

Again, referring to the plate family, it will be seen that a peak plate current of 210 ma is drawn at 50 plate volts when the grid goes approximately 55 volts positive. The peak a f cathode-to-grid voltage (E_g) will be 55 plus the bias voltage or close to 64 volts. To determine the grid driving power of a class B amplifier, refer to the plate family of curves and note the peak value of grid current (I_g) that flows when the plate voltage is minimum (50 volts) and when the grid voltage is at the crest of its cycle (+55 volts). It will be seen to be 70 ma. Grid driving power for two tubes (W_g) can now be ascertained by solving the equation:

$$W_g = \frac{I_g\,(E_g + E_c)}{2} =$$

$$\frac{0.07 \times 64}{2} = 2.24 \text{ watts}$$

The minimum effective resistance (R_g) of one modulator tube grid can also be determined for impedance-matching purposes. The formula is

$$R_g = \frac{E_g + E_c}{I_g} = \frac{64}{0.07} = 915 \text{ ohms}$$

Audio Power Requirements

The ratio of power input to the final amplifier and audio power output from the modulator is usually stated as 2 to 1 for 100% plate modulation. This ratio holds true only when sine-wave modulation is used, since it is based upon the relationship of voltages.

To illustrate with an example, consider a 100-watt class C amplifier drawing 100-ma from a 1000-volt plate supply. 100% modulation requires that the plate voltage be alternately doubled and reduced

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RCA 2BP1 2" OSCILLOGRAPH TUBE

2BP1 OSCILLOGRAPH TUBE 2"—Diameter Bulb

DATA

General:			
Heater, for Unipotential Cathode:			
Voltage (AC or DC)	6.3		Volts
Current	0.6		Ampere
Phosphor	No. 1		
Fluorescence	Green		
Persistence	Medium		
Focusing Method	Electrostatic		
Deflection Method	Electrostatic		
Base	Small-Shell Duodecal 12-Pin		
Mounting Position	Any		
Maximum Ratings, Design-Center Values:			
ANODE- No. 2 & GRID-No. 2 VOLTAGE	2500 max.		Volts
ANODE-No. 1 VOLTAGE	1000 max.		Volts
GRID-No. 1 VOLTAGE:			
Negative bias value	200 max.		Volts
Positive bias value	2 max.		Volts
PEAK VOLTAGE BETWEEN ANODE No. 2 AND ANY DEFLECTING ELECTRODE	500 max.		Volts
PEAK HEATER-CATHODE VOLTAGE:			
Heater negative with respect to cathode	125 max.		Volts
Heater positive with respect to cathode	125 max.		Volts
Equipment Design Ranges:			
For any anode No. 2 voltage (E_{b2}) between 500 and 2500 volts			
Anode-No. 1 Voltage	15% to 28% of E_{b2}		Volts
Grid-No. 1 Voltage for Visual Cutoff	0% to 6.75% of E_{b2}		Volts
Anode-No. 1 Current for Any Operating Condition	—15 to +10		Microamp.
Deflection Factors:			
DJ1 & DJ2	115 to 155 V dc/in./Kv of E_{b2}		
DJ3 & DJ4	74 to 100 V dc/in./Kv of E_{b2}		
Examples of Use of Design Ranges:			
For anode-No. 2 voltage of	*1000*	*2000*	*Volts*
Anode-No. 1 Voltage	150-280	300-560	Volts
Grid-No. 1 Voltage for Visual Cutoff	0-67.5	0-135	Volts
Deflection Factors:			
DJ_1 & DJ_2	115-155	230-310	Volts dc/in.
DJ_3 & DJ_4	74-100	148-200	Volts dc/in.
Maximum Circuit Values:			
Grid-No. 1-Circuit Resistance	1.5 max.		Megohms
Resistance in Any Deflecting-Electrode Circuit	5.0 max.		Megohms

Amateur Net **$8.75**

Features

- High deflection sensitivity
- Good sensitivity to 150 Mc
- Sharp focus over entire screen
- Improved electron-gun with zero-current first anode
- Operates with a plate supply of only 500 volts
- Individual base-pins for all deflecting electrodes

Application Considerations

1. Focus of the electron beam is accomplished by the adjustment of anode #1 voltage with respect to anode #2 voltage.
2. Spot centering may be obtained electro-magnetically or electro-statically. If the latter is used, it may be necessary to apply to adjacent deflecting plates a voltage difference as high as 2% of the dc voltage on anode #2.
3. Brightness may be increased by a reduction of the negative bias on grid #1, or by an increase of the positive voltage on anode #2.
4. For best results, anode #2 voltage should be 500 volts or higher. 1000 volts provides a brilliant trace that is clearly visible in a well-lighted room.
5. An oscillograph circuit in a 12-page technical bulletin is available on request. Write to RCA, Commercial Engineering, Harrison, N. J.

RAY GUN MONITOR

(Continued from Page 2, Column 2)

Application

The 'Ray-Gun Monitor can also be used to show a wave-form pattern. In this use, the modulated dc voltage on the horizontal deflecting plate should be replaced with 60-cycle ac. This change can be made by connecting the clip of the horizontal deflection lead to the plate of one of the high-voltage rectifier tubes.

The 'Ray-Gun Monitor is designed for use with transmitters operating at plate voltages up to about 1000 volts. The limitation is the working voltages of the various capacitors. When the Monitor is used with higher-voltage rigs, bleeders will have to be used to reduce the voltages to which the clip-leads are attached to not over 1000 volts. The bleeders can be made up of 1-megohm, 1-watt carbon resistors. These resistors should be permanently wired in the transmitters so that the 'Ray-Gun Monitor can always be put to work in a few seconds.

HAM TIPS is published by the RCA Tube Department, Harrison, N. J., and is made available to Amateurs and Radio Experimenters through RCA tube and parts distributors.

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CLASS B MODULATORS

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to zero. This would require an alternating peak voltage of 1000 volts, or an RMS voltage of $1000 \div \sqrt{2}$ or 707 volts. The 1000-volt, 100-ma class C amplifier load appears to the modulator as a pure resistance of 10,000 ohms as determined from the relationship:

$$R = \frac{E_b}{I_b} = \frac{1000}{0.1} = 10{,}000 \text{ ohms}$$

The sine-wave power required to develop 707 RMS volts across 10,000 ohms can be determined from the formula:

$$\text{Watts} = \frac{E^2}{R} = 707^2 \div 10{,}000 = 50$$

If the modulating signal were a square wave, 1000 volts would still be required for 100% modulation. But in this case, the average voltage would equal the peak voltage, therefore 100 watts of square-wave audio would be required to plate-modulate 100 watts of power input to the final amplifier. This condition is almost reached when a "clipter" is used and adjusted for maximum clipping and filtering.

When voice modulation is used, the condition is again different, although 1000 peak volts of audio power is still required. The RMS voltage of an average speech wave is less than half the peak voltage. If a figure of 50% is used, for example, the RMS modulating potential would be 500 volts, and the modulation power would be $500^2 \div 10{,}000$ or 25 watts. This is why some Amateurs figure on a 4 to 1 ratio of class C input to modulator power output.

On the above basis a pair of 811's would be capable of modulating 880 watts input to a final amplifier. However, to get the 1000 peak volts for 100% modulation, the turns ratio between primary and secondary of the modulation transformer has to be reduced. As a result, the transformer reflects a lower than proper load impedance to the modulator plates. Under these conditions, the class B modulator tubes can be quickly overloaded by a sine-wave signal from a test oscillator, or a whistle, or a soft female voice—and we should never do anything that might possibly keep those purring YL's and XYL's out of our Ham Shacks.

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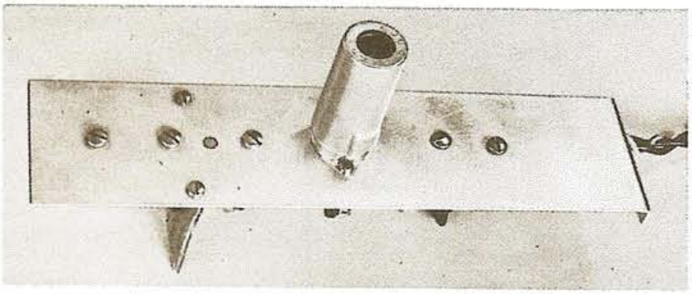
VOLUME VIII, No. 2 EDITORIAL OFFICES, RCA, HARRISON, N. J. MAY—AUGUST 1948

DELUXE TRANSMITTER USES PAIR OF 812-A TUBES IN FINAL

TURN DOWN THE GAIN CONTROLS!



This easily-built pre-amplifier unit greatly increases signal strength and improves receiver sensitivity on the popular 2 meter band.

LOW-NOISE BROAD-BAND PRE-AMPLIFIER DESIGNED FOR 2-METER RECEIVERS

By E. M. Brown, W2PAU *and* J. T. Blake, W2PFQ

Engineering Products Department, RCA

In the two-meter band, one of the best ways to improve receiver sensitivity is to add a properly designed pre-amplifier. The one described in this article will increase the signal strength two to three points on the "S" meter of a receiver and has such a high signal-to-noise ratio, that its performance is limited only by antenna noise.

The pre-amplifier is inserted in a 300-ohm feeder, between the antenna and the regular two-meter receiver. The unit has a broad-band response so that only an occasional touch-up of the tuning is necessary.

Design Considerations

On the low-frequency bands, the limit of useful receiver gain is set by QRN, man-made or natural. Signal-to-noise ratio is of minor significance and the features usually considered for determining the merit of a low-frequency receiver include such factors as bandwidth of if stages, audio response, ease of tuning, and image rejection.

On the vhf bands, atmospheric noise is practically non-existent. Man-made noise may be troublesome, but in most locations it is a minor problem. The noise which limits the performance of an ideal vhf receiver, however, is the thermal noise generated by the antenna. The thermal noise across a 300-ohm input line is equivalent to about 0.2 microvolts in a good communications-type receiver having an if band-pass of 10 kilocycles. If a gain of 5 can be obtained from a "quiet" rf pre-amplifier, the 0.2 microvolts of thermal noise can be detected by a receiving system including the pre-amplifier and a receiver capable of detecting a one-microvolt signal.

Circuit Selection

If the proper circuit is chosen, considerable reduction in tube noise generated within the amplifier stage can be achieved. Since triodes generate less noise than pentodes, it is well to consider utilizing a triode in the rf stage. Triodes in push-pull were selected for the pre-amplifier because such a circuit permits the use of a step-up antenna transformer and takes advantage of the full gain of the triode stage.

Of course, the triodes have to be neutralized but the new miniature tubes and components that are now available permit such compact circuit layouts that nearly perfect neutralization is easy to achieve. The push-pull connection reduces the input capacitance by 50% which makes for a broadly resonant, high-inductance circuit.

The RCA-6J6 twin triode was selected for this pre-amplifier chiefly

(Continued on Page 4, Column 1)

COMPACT 6-BAND 1/2-KW RIG HAS SIMPLE BAND-SWITCHING EXCITER

By Geo. H. Jones, Jr., W2CBL

This easy-to-build transmitter works as nice as it looks, on 10, 11, 15, 20, 40, or 80, with a full ½-kw input to a pair of RCA-812-A's from a 1500-volt power supply. The new 812-A handles more power and is better than the superseded 812, which makes it an attractive choice for this flexible rig. The transmitter is built on a 17"x13"x3" chassis, with a standard rack-mounting 19"x12¼" panel. The power supplies and modulator, not illustrated, are of similar construction, and are mounted in a standard 3½-foot relay rack.

Panel, chassis, and shields are constructed of aluminum to minimize rf losses, since the circuit components are compactly assembled. The layout of rf components follows in the same order as in the schematic diagram, Fig. 1, starting with the 80-meter crystals and proceeding counterclockwise to the 812-A's.

Fairly high screen and grid-biasing resistors are used in the crystal-oscillator circuit to facilitate doubling when an external vfo is used. A 560-ohm cathode resistor limits the non-oscillating plate and screen currents to a low value. Crystals X_1 and X_2 operate near the edge of the 80-meter band and can be used as band-limit markers when adjusting the vfo.

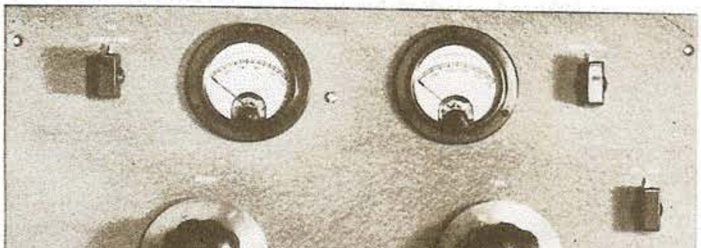
The first multiplier grid is tapped down about 1/3 from the plate end of L_1 to provide proper excitation to the following multiplier grid. A three-turn link, switched through S_2, gives ample coupling to the 807 grid tank L_5. For 80-meter operation, S_2 couples the oscillator output to the 807 grid circuit and removes plate voltage from the three multiplier stages. L_1C_5 tunes sufficiently below 3500 kc to provide excitation for the 11-meter band when multiplying eight times.

Approximately 3 milliamperes of grid drive are supplied to the first multiplier stage by the crystal oscillator, and about 10 milliamperes are delivered to the 807's.

Tank L_2C_{10} of the first multiplier stage covers double the frequency range of the crystal stage. This first multiplier drives the second multiplier through C_{11}; or, with S_2 in the "40" position, the first multiplier drives the 807's through the link coupled to L_2. Grid drive to the 807's on the 40-meter band is

(Continued on Page 2, Column 1)

BUSINESS-LIKE AND EFFICIENT



The efficient manner in which this versatile rig was designed and constructed is reflected in its panel symmetry.

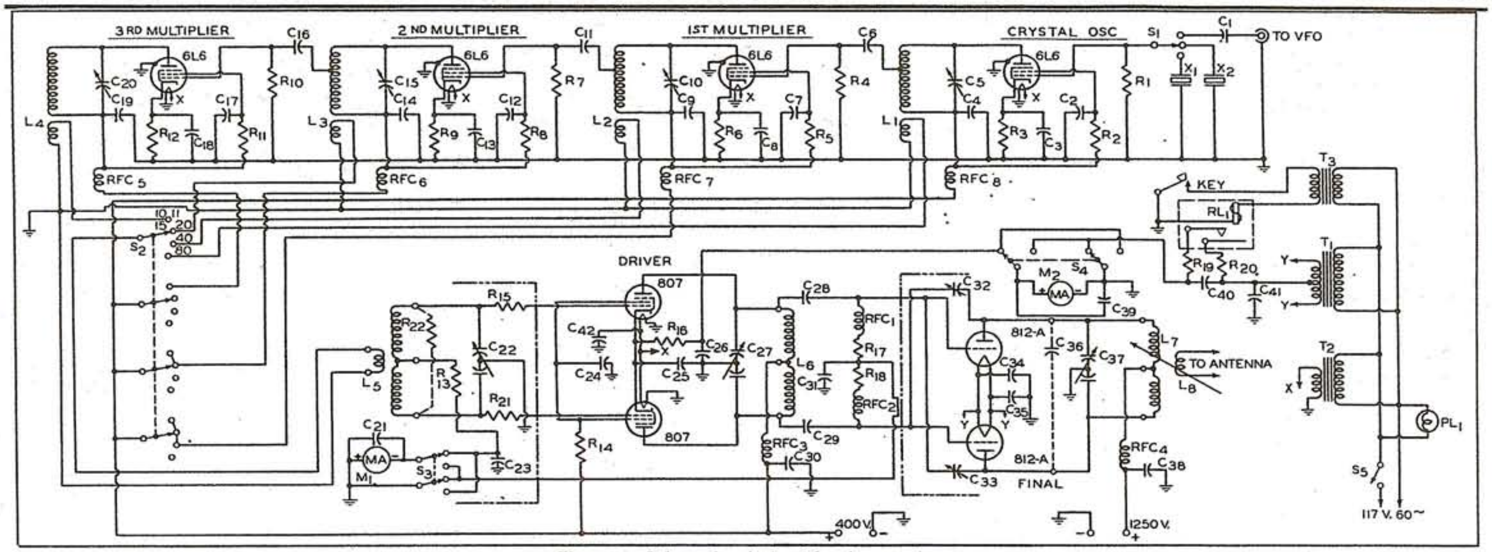


Figure 1. Schematic of the 6-band transmitter.

COMPACT 6-BAND RIG

(Continued from Page 1, Column 4)

practically the same as when operating directly from the crystal oscillator on the 80-meter band.

For 20-meter operation, L_3C_{15} is tuned to four times the oscillator frequency; for 15-meter work L_3C_{15} is tuned to six times the oscillator frequency. Equal excitation (10 milliamperes) is delivered to the 807 grids when doubling or tripling. With S_2 in the "15-20" position, plate voltage is applied to the second multiplier and the link-coupling circuit is completed between L_3 and L_5.

The third multiplier tank L_4C_{20} covers a frequency range eight times that of the crystal stage, and supplies 10- and 11-meter drive (10 milliamperes) to the 807's when S_2 is in the "10-11" position.

Circuit Symmetry

Suitable values of L_5 must be plugged-in to operate on the various bands. On 80, 40, and 20, it was found desirable to shunt L_5 with the 20,000-ohm resistor R_{22} for suppression of normal-frequency parasitics. No shunting resistor is needed for the 10-meter coil. The 33-ohm resistors R_{15} and R_{21} are parasitic-oscillation suppressors and are mounted as closely to the socket pins as possible.

The 807 stage was laid out with considerations of circuit symmetry and good shielding between plate- and grid-tank circuits, since this stage operates at all times with grid and plate circuits at the same frequency. Two 807's are used to provide push-pull excitation to the 812's with simple circuit means. Plug-in coils are used in the grid and plate circuits of this stage. Standard B&W coils cover the 80-, 40-, and 20-meter ranges, but the plate coil required modification for the 10-meter band. For 10-meter operation, L_5 is a 6-turn coil 1¼ inches in diameter, wound 3 turns per inch with No. 10 wire.

Due to effective shielding and layout, the 812-A final is stable when neutralized. The stage is neutralized with the transmitter adjusted for 10-meter operation. Once C_{32} and C_{33} are set, no further adjustment is necessary when other plug-in coils are used.

Standard B&W coils for the 812-A final were found satisfactory for operation on the 10-, 20-, and 40-meter bands, but the 80-meter coil required modification. Four turns were removed from each outside end of this coil to obtain an improved L/C ratio. Plug-in capacitor C_{36} is a fixed padding capacitor which is used only for 80-meter operation; it is removed when shifting to higher frequency bands. Grid drive to the final (read on M_1) runs 50 to 60 milliamperes under full plate power input to the final.

Filament center-tap keying is used because it gives clean keying and because the transmitter is completely self-biased. With key up, the filament circuit may rise to a maximum of 480 volts above ground. C_{40}, R_{19}, and R_{20} comprise a filter which materially reduces key clicks.

The plate-power requirements are simple: a 400-volt, 200-milliampere supply for the crystal oscillator, multiplier stages, and the push-pull 807 driver stage; and a 1500-volt, 350-milliampere supply for the 812-A final stage will fill the bill.

No special tools or fittings are required for construction of the transmitter. Shielding construction is all of flat aluminum with no forming other than right-angle bends for mounting to the chassis and panel.

The plate-circuit components and tubes for the driver stage are above and on the left-hand front portion of the chassis. The final 812-A tubes are mounted in a horizontal position through the inter-stage shield between the 807 and final stages, with the filaments in a vertical plane. The neutralizing capacitors and plate-circuit components for the final stage are on the front right-hand portion of the chassis. This layout affords short and direct coupling from stage to stage and allows front-panel controls to be brought out in a symmetrical arrangement.

Metering and switching is provided for reading grid current to the 807 or 812-A stages on one meter, and cathode or total tube current on another meter. This metering is ample for complete tuning of the transmitter on all bands and keeps the meters at ground potential.

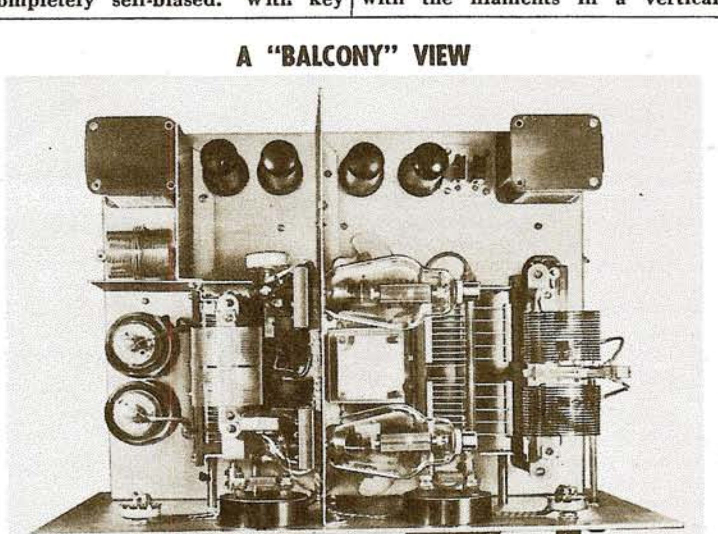
Shock Proof Panel

One important feature of the transmitter is its shock-proof front panel. One terminal of each meter is bonded to the panel. The two final-stage tank-tuning capacitors are mechanically grounded, and all switch shafts are grounded metal. The oscillator-, multiplier-, and antenna-coupling shafts are insulated, but pass through grounded ¼-inch bushings at the front panel.

There are four small inter-shield panels, all made of 1/16-inch aluminum. One of these is mounted under the chassis 4 inches from the rear edge. The crystal oscillator is mounted on this shield, in addition to three multiplier tuning capacitors and switches S_1 and S_2. A second inter-shield is mounted above the chassis just to the left of center, separating the 807 and 812-A stages. Two other small shields are used to box off the 807 grid coil and shield it from the 807 plate coil.

Mounting of other parts is evident from the illustrations. Besides the four inter-stage shields, there are two rear support brackets for the 807 and 812-A plate-tuning capacitors. A lucite panel is used to insulate the crystal-oscillator and multiplier tuning capacitors. Three-quarter inch holes were first punched in the under-chassis shield for the four capacitors; the lucite strip was then mounted behind this

A "BALCONY" VIEW



Good shielding between plate and grid-tank circuits was incorporated in the compact ½ kw rig.

shield and shaft-bushing clearance holes were drilled concentric with the ¾-inch holes for the tuning capacitors.

Band switch S_2 was partially disassembled and the rf-link switching section was reassembled behind the under-chassis shield panel. The crystal switch S_1 is mounted behind this panel on the left-hand end. This switch is wired to a coaxial connector on the chassis so that excitation from an external vfo can be brought to the transmitter. When using an external vfo, its frequency should be one-half that of the normal crystal frequencies; the 80-meter stage is then used as a doubler and operates the same as the other multiplier stages in the transmitter.

Cabinet Considerations

All parts can be mounted before wiring with the exception of the tank coils, the links for the crystal oscillator, and three multiplier stages, and the tuning capacitor C_{22} for the 807 stage. With these parts out, all socket lugs and wiring points are accessible for wiring.

A transmitter of these voltage and power requirements should be completely encased in a grounded metal cabinet for elimination of shock hazard. The metal cabinet also helps to reduce harmonic radiation and television interference. (See page 166 of the ARRL Handbook, 1948 edition). If ventilating louvers are used, they should be covered completely with close-meshed screening on the inside of the cabinet.

Tuning of the transmitter is simple, once the operator becomes acquainted with the controls. A change from band to band can be made in less than two minutes.

The first tune-up should be made on 80 meters. With the 80-meter coils plugged into positions L_5, L_6, L_7, with C_{36} inserted and S_2 turned to the "80" position, the unit is ready for tuning. Oscillator tuning control C_5 is tuned until a change in 807 cathode current (read on M_2) is noted. This change indicates that the crystal is oscillating. C_{22} is then tuned to resonance to give maximum grid drive to the 807 stage (read on M_1 with S_3 in the proper position). *CAUTION: When the final tank is out of resonance, excessive plate dissipation must be avoided by reducing the plate voltage, or by tapping the key rapidly.*

Tuning Details

The plate circuit of the 807 stage is then tuned to resonance (indicated by minimum current as read on M_2). The 812-A final stage should next be neutralized. With the plate voltage off, and key down, C_{32} and C_{33} are adjusted until there is no dip in the final grid current when tuning the final tank capacitor C_{37} through resonance. The final grid current (read on M_1 with S_3 in the proper position) will be approximately 75 milliamperes with plate voltage to the stage off. This current will fall to approximately 60 milliamperes with plate voltage and full loading applied.

The transmitter is next tuned up on 40 meters. Coils L_5, L_6, L_7 are changed, and C_{36} is removed. (Note that C_{36} is left out on all bands except 80 meters). Band switch S_2 is changed to the "40" position. C_5 is left unchanged, and with the crystal stage oscillating as tuned for 80 meters, C_{10} is next tuned until a change is noted in the 807 cathode current, as observed when tuning-up on "80". After this current change is noted, tune-up the 807 and 812-A stages as explained for "80". C_{32} and C_{33} should not need adjustment if properly set in the first tune-up.

Tuning on 20 or 15 meters follows next. Proper coils are inserted at L_5, L_6, L_7, and S_2 is turned to the "15-20" position. C_5 and C_{10} are unchanged, and 40-meter drive is supplied to the grid of the 15-20 meter multiplier stage. C_{15} will give two indications of resonance: the first point, at double frequency of the previous multiplier, occurs when C_{15} is adjusted to nearly full capacitance, and supplies 20-meter drive to the 807 grids. The second point occurs near minimum capacitance of C_{15}, and provides 15-meter drive to the 807 grids. Tuning of the 807 and 812-A stages is accomplished as before.

Tune-up on 10 or 11 meters as follows: insert the proper coils at L_5, L_6, L_7. Turn S_2 to the "10-11" position. Leaving C_5, C_{10}, and C_{15} set for 20-meter operation, C_{20} is then tuned for a current change in the 807 cathode circuit as explained above. The 807 and 812-A stages are tuned as before.

Note that the frequency coverage of L_4C_{20} does not include 7.5 meters, so that if the tuning of the 15-20 meter multiplier is set at 15 meters, no resonance point will be found for the 10-11 multiplier.

Once the transmitter has been tuned up on the various bands, approximate settings of all controls will be known, and changing from band to band will become a simple operation.

PARTS LIST

C_1 C_6 C_{11} C_{16} = 0.0001 μf, mica, 500 working volts

C_2 C_3 C_4 C_7 C_8 C_9 C_{12} C_{13} C_{14} C_{17} C_{18} C_{19} C_{23} C_{24} C_{25} C_{26} C_{30} C_{31} C_{42} = 0.005 μf, mica, 500 working volts

C_{21} C_{39} = 0.01 μf, mica, 300 working volts

C_{28} C_{29} = 0.0001 μf, mica, 1200 working volts

C_{34} C_{35} C_{41} C_{42} = 0.002 μf, mica, 500 working volts

C_{38} = 0.002 μf, mica, 3000 working volts

C_{40} = 0.05 μf, oil-filled paper, 500 working volts

C_5 = ZU140AS Cardwell Trim-air capacitor

C_{10} C_{15} = ZU75AS Cardwell Trim-air capacitors

C_{20} = ZR25AS Cardwell Trim-air capacitor

C_{22} = EU100AD Cardwell capacitor

C_{27} = MT100GD Cardwell capacitor

C_{32} C_{33} = NA10NS Cardwell capacitor

C_{36} = JCO-50-OS Cardwell capacitor

C_{37} = XG-50-XD Cardwell capacitor

R_1 R_4 R_7 R_{10} = 47,000 ohms, carbon, 1 watt

R_2 R_5 R_8 R_{11} = 47,000 ohms, carbon, 2 watts

R_3 R_6 R_9 R_{12} = 560 ohms, carbon, 2 watts

R_{13} = 10,000 ohms, carbon, 10 watts

R_{14} = 15,000 ohms, 10 watts

R_{15} R_{21} = 33 ohms, carbon, 1 watt

R_{16} = 250 ohms, 10 watts

R_{17} R_{18} = 5000 ohms, 10 watts

R_{19} R_{20} = 50 ohms, 10 watts

R_{22}* = 20,000 ohms, carbon, 1 watt

M_1 = Weston 301, 150 milliamperes

M_2 = Weston 301, 500 milliamperes

L_1 = B & W Miniductor No. 3016; 35 turns wound 32 turns per inch, 1″ diameter, tapped at 10 turns from plate end; 3-turn link spaced ⅛″ from ground end

L_2 = B & W Miniductor No. 3015; 22 turns wound 16 turns per inch, 1″ diameter, tapped at 7 turns from plate end; 3-turn link spaced ⅛″ from ground end

L_3 = B & W Miniductor No. 3014; 10 turns wound 8 turns per inch, 1″ diameter, tapped at 3 turns from plate end; 3-turn link spaced ⅛″ from ground end

L_4 = B & W Miniductor No. 3014; 7 turns wound 8 turns per inch, 1″ diameter; 3-turn link spaced ⅛″ from ground end

L_5 = B&W Type JCL; 5-pin socket mounting

L_6 = B&W Type B; center-tapped coil without link

L_7 = B&W Type TVL, variable linked, center-tapped

L_8 = B&W swinging link and base for TVL coils

T_1 = Filament Transformer, 2.5 volts, 5 amperes

T_2 = Filament Transformer, 6.3 volts, 8 amperes

T_3 = Filament Transformer, 6.3 volts, 8 amperes

S_1 = Mallory Hamband Switch, 4 pole, 1 section

S_2 = Mallory Hamband Switch, 4 pole, 4 section

S_3 S_4 = Shorting-type Switches, 2 pole, 2 section

S_5 = SPST Switch

RFC_1 RFC_2 RFC_5 RFC_6 RFC_7 RFC_8 = National Type R-100 Chokes, 2.5 millihenries

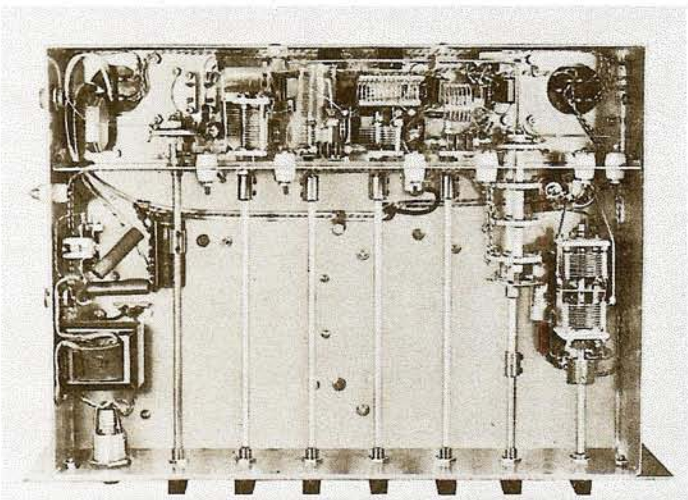
RFC_3 = National Type R-300 Choke

RFC_4 = National Type R-154U Choke

RL_1 = Keying Relay, 2.5 volt winding

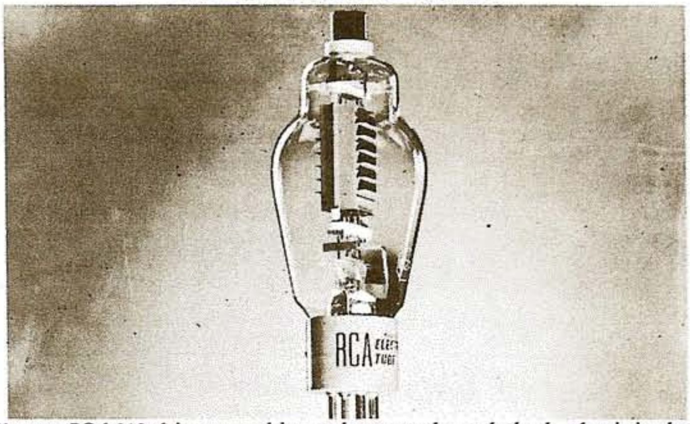
* One resistor mounted across each coil for 80-, 40-, and 20-meter bands on L_5.

A "BOTTOMS UP" VIEW



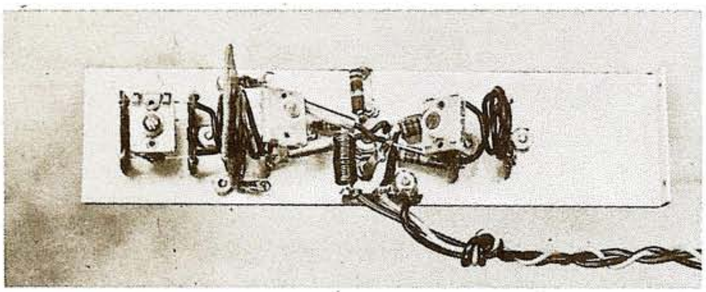
The logical placement of components and wiring on a 17″x13″x3″ chassis was a major consideration in the transmitter's design.

NOW—A BETTER TRIODE



The new RCA-812-A is easy to drive, and easy on the pocketbook. A pair in class B can deliver 340 watts of audio at 1500 plate volts (ICAS rating). A single 812-A will handle an input of 260 watts (ICAS rating) in class C telegraphy up to 30 Mc. At $3.75, it's an excellent buy in its class.

EASILY BUILT PRE-AMPLIFIER



Simplicity and low cost components do not detract from the effectiveness of the 2 meter pre-amplifier.

LOW-NOISE PRE-AMPLIFIER

(Continued from Page 1, Column 2)

because of one feature—it has only one cathode, and one cathode lead. In a push-pull class A circuit, no rf current flows through the cathode lead, and, consequently, degeneration due to cathode lead inductance is eliminated. As a result, the grids of a properly neutralized 6J6 present an input load of better than 10,000 ohms at 144 megacycles. By way of comparison, the 6AK5 rf pentode has an input resistance of approximately 3,000 ohms, a value less than one-third that of the 6J6.

The low interelectrode capacitance of the 6J6 also aids in making the amplifier broad band. A voltage gain of 8 to 10 can be obtained over the entire 144-148 megacycle band with this tube.

The tube noise of an amplifier stage containing a 6J6 should be, theoretically, about 1.5 to 2 times the thermal noise. The corresponding value for a 6AK5 is about 3 times the thermal noise. This difference may often be enough to bring some weak signals up out of the noise level so that they may be copied.

Construction Details

This low-noise broad-band pre-amplifier is built on a small sheet of metal. Six bakelite solder lug terminal strips are used. Ceramic and other low-loss mounts will not improve the performance.

The antenna coil is tuned in order to compensate for a possible serious mismatch in the feeder system and to provide a flatter response than a single-tuned circuit provides. The coil requires a tuning capacitance of about 20 to 30 uuf which can be well provided by a mica compression-type trimmer capacitor. Mica trimmers introduce small losses at low capacitance settings, their leads are short, their stray capacitances are nearly balanced to ground, and they are not expensive.

Electrostatic Shield

An electrostatic shield is used between the antenna coil and the grid coil. At first glance, this shield may seem superfluous, but when the possibility of the long feeders picking up noise or signals from powerful local stations is considered, it seems wisest to be on the safe side and include an electrostatic shield.

The shield can be made as follows: Fold a piece of plastic about 2" x 4" x 1/32" into a 2" x 2" square. Then, wind a flat coil of cotton- or silk-insulated copper wire (approximately #22 AWG) along most of the length of this flat form. Sandpaper the insulation off one side of the coil and lay a piece of heavy tinned copper bus wire along the edge. Solder each turn of the flat coil to the bus wire, but *be very careful not to melt or ignite the plastic.* Coat one side of the assembly liberally with household cement or coil dope. After it is thoroughly dry, cut the uncoated side away with a pair of tin snips. When completed, the shield looks like a "picket fence" of copper wires with the tips of the pickets all insulated from each other, and the bottoms all soldered to the heavy bus wire.

Grid Coil Construction

The grid coil is of the "figure-eight" variety made from solid plastic-insulated wire. This type of coil has balanced stray capacitances to ground and can be backed right up to the electrostatic shield without becoming unbalanced. Figure 2 shows the development of this winding. Some slight spreading or squeezing may be required to permit tuning the coil with the lowest possible value of grid-tuning capacitance.

The connections between the terminal strip on which the grid coil is mounted and the grid terminals of the tube socket (No. 5 and No. 6) are made with thin tubing, not wire. These tubes can be brass or copper with a bore of about 1/16 of an inch, or they can be made by rolling a strip of soft copper foil into a tubular cylinder. The socket connections are soldered so that the holes in the ends of the connecting tubes are exposed and accessible.

The grid coil is tuned by means of a 1-to-20-uuf compression-type mica capacitor. In practice, this trimmer is run almost wide open.

The neutralizing "capacitors" are short lengths of plastic-insulated #18 wire inserted about ½ inch into the grid-connecting cylinders. Some slack in the wires should be left for adjustment.

The rf plate tank is identical with the rf grid tank. No bypass capacitors or plate chokes are needed. On the assumption that the output line will be coupled tightly to a tuned circuit in the next stage, the output coil is not tuned.

Adjustment and Test

For the adjustment of this pre-amplifier, no special test equipment is needed. The procedure is as follows: Tune in a strong local signal near the middle of the band on your regular station receiver. Insert the pre-amplifier in the antenna feed line. It is well to mount the unit at a point two or three feet from the receiver, especially if the receiver is not fully shielded.

Turn on the heater voltage of the 6J6 but not the plate voltage. The signal should still be present, but weak. Then, peak up the trimmers for maximum signal. Next, with a fiber screwdriver work the neutralizing leads in and out of the tubular grid connectors. A definite signal null point should be encountered. A very great reduction in feed-through signal can be obtained when optimum neutralization is reached.

Properly neutralized, the 6J6 will not oscillate even though it is lightly loaded. From a standpoint of signal-to-noise ratio and bandwidth, however, it is best to use tight coupling in both plate and grid coils. Push the coils together and at the same time trim the tuning adjustments for greatest gain in the center of the band until the point of maximum gain is reached *and passed.* The unit should be operated with the coils over-coupled.

If everything has been done correctly thus far, the pre-amplifier is ready to operate. Turn on the plate voltage and stand by to turn down the gain controls!

PARTS LIST

C1	30 uuf (at mid-range) Mica-Sandwich Trimmer
C2 C3	1.5 uuf to 25 uuf Mica-Sandwich Trimmer
L1 L4	1 full turn #18 AWG plastic-insulated solid wire, ⅝" ID
L2 L3	See Figure 2, and text
L5	2-meter rf choke (20 inches, approximately, of #24 enameled wire, wound on ¼" dia. form.)
R1 R2	560,000 ohms, carbon, ¼-watt
R3	56 ohms, carbon, ½-watt
R4 R5	47,000 ohms, carbon, 1-watt

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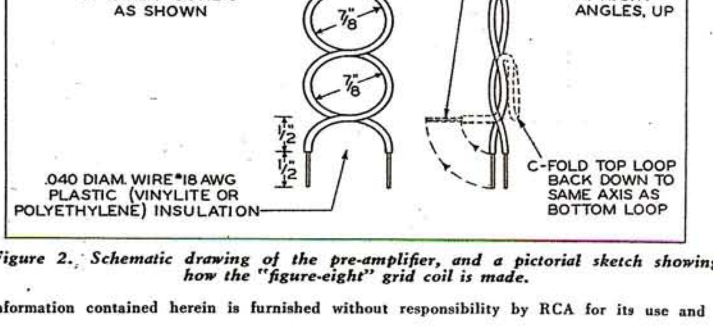

Figure 2. Schematic drawing of the pre-amplifier, and a pictorial sketch showing how the "figure-eight" grid coil is made.

RCA Ham Tips

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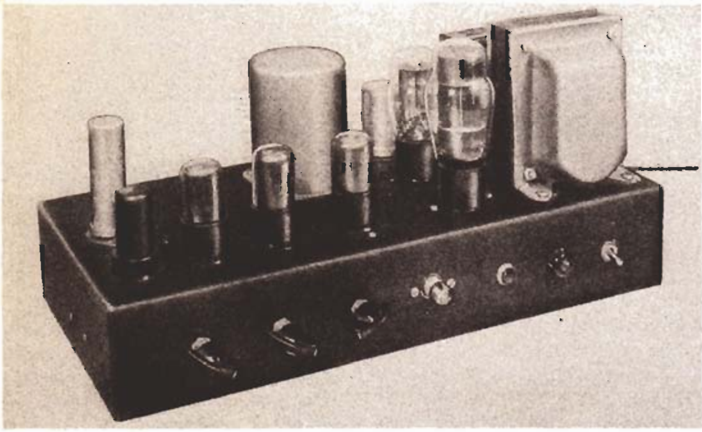
VOLUME VIII, No. 3 EDITORIAL OFFICES, RCA, HARRISON, N. J. SEPTEMBER—OCTOBER 1948

VERSATILE NBFM TRANSMITTER DESIGNED FOR MOBILE USE

Hi-Fi AMPLIFIER



Featuring a low cost resistance-coupled driver stage and independent tone-control circuits for bass and treble, the amplifier delivers 10 watts of audio power with less than 2% distortion

HIGH-FIDELITY AUDIO AMPLIFIER DELIVERS 10 WATTS POWER OUTPUT

By D. P. HEACOCK
Application Engineering Group,
RCA Tube Department

Since the announcement of the RCA-6AS7-G twin power triode, many engineers and experimenters have been asking, "How can we use this tube in a high-fidelity audio amplifier?" Although an initial step in this direction was taken in a speech amplifier previously described in HAM TIPS, the amplifier described in this article goes all the way and gives a wide-range high-fidelity amplifier design capable of delivering 10 watts of audio power in the secondary of the output transformer with a distortion of less than two per cent. At a power output of ½ watt, which is a typical operating value for a home installation, there is practically no distortion (see Figure 3 for distortion characteristic of entire amplifier).

The amplifier features a low-cost resistance-coupled driver stage and independent tone-control circuits for bass and treble. It has sufficient gain to be driven by any medium-output crystal pickup such as the RCA Magic Tone Cell (RCA 211X1) which can be purchased either separately or as part of a crystal phonograph pickup arm assembly, RCA 209X1. By adding a pre-amplifier tube to the amplifier, it can also be used with any of the low-output magnetic-type pickups. A pre-amplifier with suitable compensation for this type of pickup is included in the circuit diagram, Figure 4. A stage-by-stage description of the amplifier follows.

Output Stage

The output stage uses the 6AS7-G operating in a class A push-pull circuit. Two separate cathode-bias resistors are used for bias on the two triode sections. The regulation produced by these two resistors makes it generally unnecessary to provide any special balancing circuit to equalize the current in the two triode units. The plate-supply voltage is 375 volts and the plate current per triode unit is 50 ma. Thus, the developed bias is 125 volts and the effective plate voltage is 250 volts. Each cathode is bypassed with an electrolytic capacitor to eliminate degeneration. Since the 6AS7-G is

(Continued on Page 3, Column 2)

10-METER RIG WITH 2E26 FINAL OPERATES ON BOTH PHONE AND CW

By H. W. BROWN, JR., W2OQN, ex-W1KIQ
Aviation Transmitter Section
RCA Victor Division

Here is a little rig, a complete 28-Mc transmitter, which can afford the operator much pleasure in either a mobile or fixed station location. This rig will especially hit the spot for those who travel by automobile and are away from home a lot. It is small, light, and versatile enough so that it can be carried about and set up at any location with not much more effort than hooking on the antenna and plugging into an appropriate power source. The transmitter features push-to-talk nbfm, or cw operation in either the 10- or 11-meter band. The power supply may be operated from either 6 V dc or 110 V ac.

Crystal Reactance FM

The basic device used for obtaining frequency modulation is something new and is known as the Gerber Crystal Reactance System. Its principle of operation briefly is as follows. An inductor, which is tuned slightly higher than the crystal frequency, is inserted in series with the crystal. The total inductance in the oscillator grid circuit is, therefore, increased. In order to meet the conditions for oscillation, the crystal will then assume a lower value of equivalent inductance and a lowering of the crystal operating frequency will result. In Figure 1, a typical reactance curve for a crystal, f_1 and f_2 designate points of series and parallel resonance, respectively. Point f_a is an operating point which meets the necessary conditions for operation. When an inductive reactance is added to the circuit, the crystal is required to adjust itself to a new frequency marked f_b for the total reactance to remain constant. If the magnitude of the added inductance is then varied electronically, as with a reactance-tube modulator, the crystal frequency will then swing up and down along the crystal reactance characteristic. Extremely wide deviations are possible with this system; deviations in the neighborhood of 20 kc are not uncommon at even 3 Mc. In this particular application, however, no such deviation is necessary.

(Continued on Page 2, Column 1)

READY FOR ACTION!

This efficient looking rig features the new crystal reactance system for obtaining frequency modulation. It's a natural for Amateurs who do a lot of travelling by automobile.

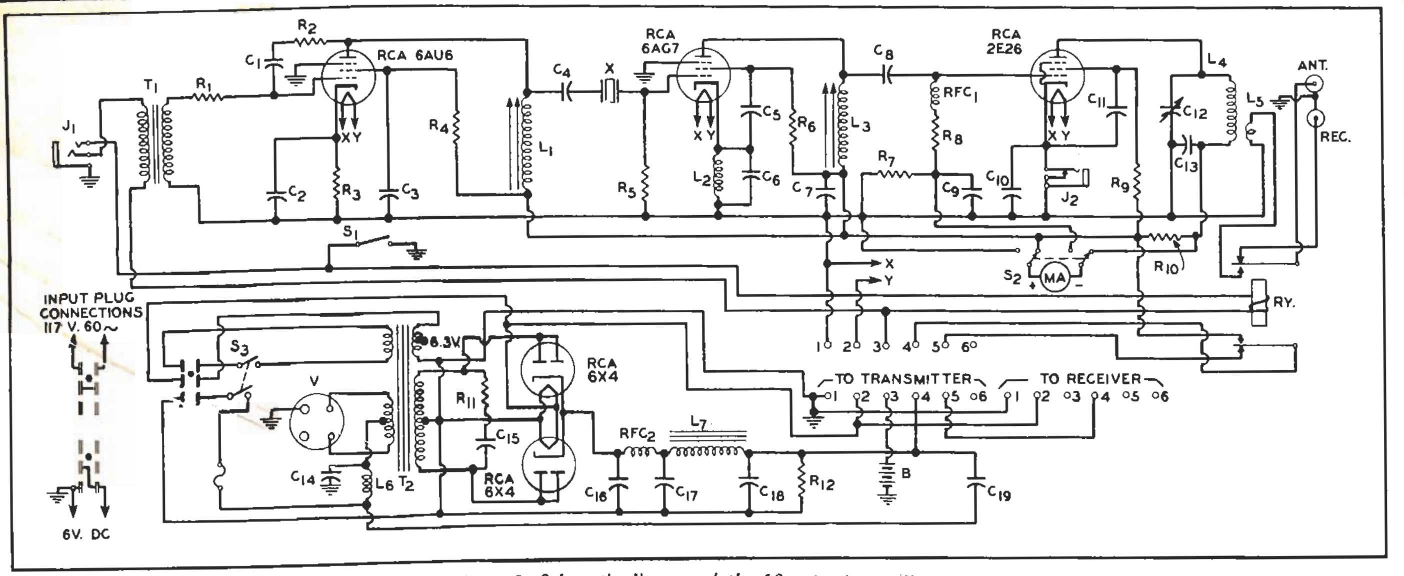


Figure 2. Schematic diagram of the 10-meter transmitter.

MOBILE RIG

(Continued from Page 1, Column 4)

RF Section

The crystal oscillator operates with a 7-Mc crystal and L_1 is the series inductor which produces the frequency deviation. The 6AG7, an excellent tube for oscillator-multiplier service because of its high control-grid screen-grid Mu factor, quadruples to 28 Mc. The

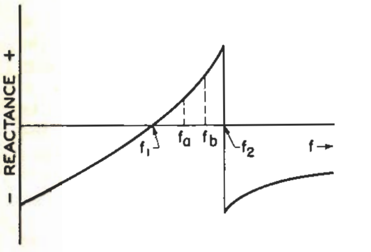


Figure 1. Typical reactance curve for a crystal.

output of the 6AG7 drives a 2E26 final of conventional design to about 10 watts using the described power supply. The oscillator is basically a standard "Hot-Cathode Colpitts" circuit with a few modifications. Because it is desirable in this application to have good harmonic output consistent with low crystal current, the screen of the 6AG7 is bypassed to the cathode, and instead of a conventional 2.5-mh choke in the cathode tank circuit, an Ohmite Z-1 choke (L_2) is used. This choke resonates closer to the crystal frequency, increasing the harmonic output considerably. Because the series inductor and the reactance tube introduce some losses into the oscillator, these two special design features are necessary so that ample drive is available for the final.

The reactance-tube modulator is conventional and uses a 6AU6 miniature pentode, which operates very satisfactorily. Adequate drive to obtain sufficient deviation is available directly from the microphone transformer.

The table below gives voltage and current measurements for the rf section.

	6AU6	6AG7	2E26
Plate volts	290	290	290
Plate milliamperes	3	30	60
Input watts	0.87	8.7	17.4
Screen volts	150	240	180
Screen milliamperes	2	6	10
Control-grid milliamperes	—	—	2.2
Power-output watts	—	--	10

A T-17B surplus Army single-button carbon microphone was used with this rig, the push switch on the mike performing the dual function of energizing the send-receive relay which switches the antenna and B+ from the receiver to the transmitter and controlling the mike current. Because the transmitter was designed to work from either a dc or ac input, it was necessary to include a microphone battery. If only dc operation is contemplated the relay and mike voltage may be obtained from the main storage battery.

It may be observed that there is no front panel control for the oscillator tuning. It was found that if the slug on L_0 is set for middle-of-the-band operation, there is no appreciable difference in power output when crystals of other frequencies are used. It proved necessary, however in the interest of efficient operation to provide a tank tuning control on the 2E26 final amplifier.

L_1 should be adjusted to the point where a frequency shift of about 5 kc is observed between the conditions when it is shorted out and when it is in the circuit. It is comparatively simple to adjust the deviation merely by listening to the modulation frequency in a receiver and setting L_1 accordingly; however, it is desirable to check the actual deviation by any of the usual methods.

It may also be noted that provision (J_2) has been made for keying the 2E26 cathode circuit. So that one would not have to keep the mike button depressed to hold in the relay, a separate phone-cw switch, S_1, has been provided. This switch closes the circuit to the relay.

Metering is accomplished by switching a meter (0-10 ma) from the grid to the plate of the 2E26. When plate current is measured, a shunt is automatically connected into the circuit which multiplies the meter readings by 10. The exact value of this shunt (R_{10}) may be calculated or it may be determined by cut-and-try methods.

Construction and Layout Details

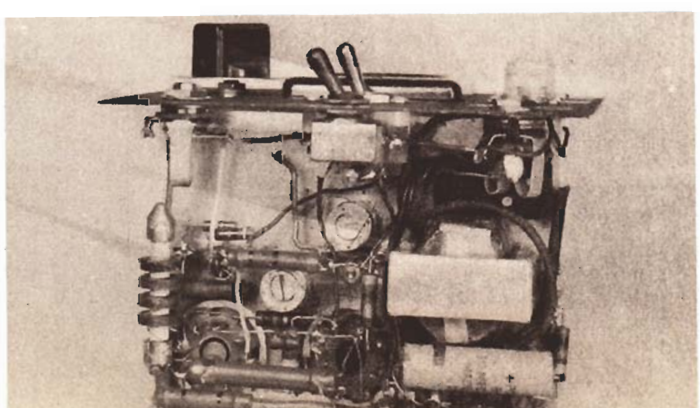
The entire rf section is built into a 4" x 5" x 6" standard cabinet. The chassis layout is illustrated in the photo on bottom of page 3. From left to right may be seen the relay and the 6AU6, the 6AG7, and the 2E26 with its tank circuit. The deviation control L_1 is under the meter while the oscillator-tank tuning slug is between the 6AG7 and the 2E26. The rf output is brought out to standard co-ax connectors on the front panel.

Power Supply

As mentioned above, the power supply is designed to work from either a 6-volt battery or 110-volts ac. To accomplish this a Thordarson transformer (type T-22R24) with a dual input is used in conjunction with a vibrator. For battery operation, of course, it is desirable to run the filaments from the dc source, so a switching arrangement is included with the power input plugs. A heavy-duty male 6-connector Jones plug on the chassis is used for input and two matching female receptacles are used on the power cables. Connecting the appropriate plug to the unit automatically makes the proper filament connections. Two miniature 6-connector female chassis-mounting-type Jones receptacles are used for output power and con-

(Continued on Page 3, Column 1)

BACK STAGE SCENE



An underchassis view of the transmitter reveals simplicity of construction and the compact manner in which wiring and components are arranged.

MOBILE RIG

(Continued from Page 2, Column 4)

trol circuits: one feeds the transmitter and one the associated receiver. A pair of 6X4 rectifier tubes, connected in parallel, will furnish more than enough current to operate the transmitter. Approximately 300 volts is available from the supply.

PARTS LIST

R_1, R_2, R_4 = 68,000 ohms
R_3 = 680 ohms
R_5 = 47,000 ohms
R_6 = 8,200 ohms, 1 watt
R_7 = 47 ohms
R_8 = 10,000 ohms
R_9 = 10,000 ohms, 5 watts
R_{10} = Meter Shunt
R_{11} = 5,000 ohms, 1 watt
R_{12} = 220,000 ohms
C_1, C_6, C_8 = 100 $\mu\mu f$, 600 W.V. (Hi-Kap)
C_2 = 10 μf, 25 W. V.
C_3 = 1μf, 400 W. V.
C_4 = 1,500 $\mu\mu f$
C_5, C_7, C_9, C_{10}, C_{11}, C_{13} = CRL Hi-Kaps, 5,000 μf, 600 W. V.
C_{12} = 15$\mu\mu f$, Variable, Johnson 160-107
C_{14} = 5μf, 200 W. V.
C_{15} = .01 μf, 1,600 W. V.
C_{16} = .01 μf, 600 W. V.
C_{17} = 8 μf, 450 W. V.
C_{18} = 30 μf, 450 W. V.
C_{19} = 100 $\mu\mu f$, mica
V = Vibrator, Mallory 825C
Ry = Relay dpdt, 6 volt dc
F = Fuse, 25 amp
RFC_1, RFC_2 = 2.5 mh
B = 6 V. Battery, RCA-VS009
T_1 = Microphone transformer, Stancor A-4706
T_2 = Dual Power transformer, 6 volts & 110 volts input, Thordarson T-22R24
J_1 = 3 conductor microphone jack
J_2 = Key jack, closed circuit
S_1 = SPST toggle switch
S_2 = DPDT toggle switch
S_3 = DPST toggle switch, 15 amp.
Ma = 0-10 ma DC meter 3"
L_1 = 37 turns, #30 enamelled, 2 layers on Millen Form #69041
L_2 = Ohmite Z-1 choke
L_3 = 10 turns, #24 enamelled on Millen Form #69041
L_4 = 10 turns, #16, ¾" diameter, ¼" long (air wound)
L_5 = Antenna link—3 turns, #16 over cold end of L4
L_6 = Hash choke, Mallory—RF583
L_7 = Filter choke—Stancor C-1421
X = Appropriate 7 Mc crystal
NOTE: All resistors ½ watt unless otherwise noted.

AUDIO AMPLIFIER

(Continued from Page 1, Column 2)

a cathode type tube, the heater supply (6.3 volts, 2.5 amperes) is obtained from the same transformer winding used for the other tubes in the amplifier.

Throughout the amplifier, resistance-coupled triode amplifier stages are used. Consequently, the circuit component mainly responsible for determining the frequency response of the amplifier is the output transformer. Use of a low-price, low-quality output transformer is simply not good economy in a high-quality audio system. After some experimentation with transformers in various price ranges, a UTC CG-16 transformer was selected as one of the reasonably priced transformers with good characteristics.

Driver Stage

It has been generally believed that adequate voltage for driving the 6AS7-G could be obtained only by the use of a transformer-coupled driver stage. This type of circuit is used in the speech amplifier mentioned previously. For such an application, transformer coupling is excellent because it provides the frequency cutting so desirable in a unit designed to handle voice-frequency components only. It is an expensive proposition, however, to use a truly high-fidelity audio interstage transformer in a high-fidelity wide-range amplifier. Considerable work was done, therefore, to devise a way to drive the 6AS7-G with a resistance-coupled push-pull driver. The circuit which was finally evolved uses a 6SN7-GT with a plate supply of 375 volts. Because of the voltage drop in the plate load resistors, operation is well within tube ratings. Degeneration, introduced into the circuit by the use of unbypassed cathode resistors, tends to reduce distortion in the output signal to a very small value. The grid resistors of the triodes in the driver stage are returned to the junction of the series cathode resistors to provide the correct bias.

Excitation for the driver stage is obtained from the familiar split-load phase inverter. This method was used in preference to the more common one of obtaining the grid signal voltage for one driver tube by tapping off the load of the other driver stage. The reasons for this choice are: first, the over-all distortion is slightly less because the grids of both driver units are provided with an undistorted signal. Further, the circuit employed is inherently balanced and requires no careful balancing after completion in order to determine the proper point for tapping off the signal for the second driver unit.

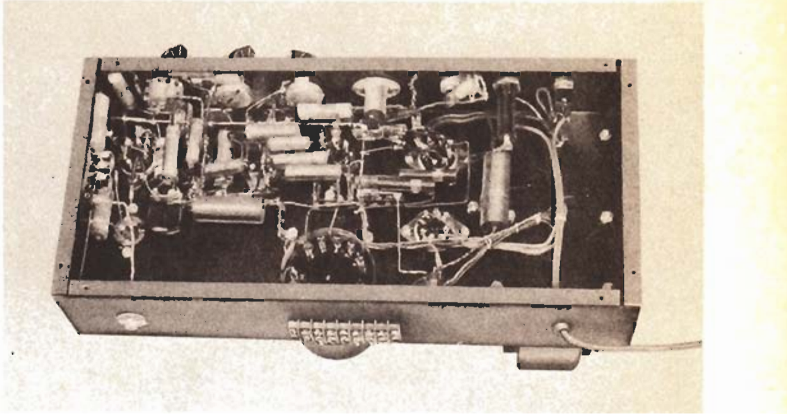
Tone Control Stages

Preceding the phase inverter are three additional triode amplifier stages. In order, working back from the phase inverter, these stages are the treble tone-control stage, a voltage amplifier stage, and the bass tone-control stage. In the design of tone control stages several features are desirable. Separate controls should be provided for both bass and treble frequencies; there should be no interaction between the controls; and frequency boost and frequency attenuation should be obtained from the same control without switching. Further, it was considered desirable to avoid the use of any inductors not only because of cost, but also because of possible hum pickup problems.

Interaction between the bass and treble tone controls is eliminated by putting each in a separate stage. The treble tone-control stage is a resistance-coupled amplifier stage with a large unbypassed cathode resistor. A potentiometer (R_{23}) in series with a 0.005-μf capacitor (C_{17}) is connected between the plate of the tube and the junction of the two cathode resistors. From the arm of the potentiometer a capacitor is is connected to ground. When the arm of the potentiometer is at the plate end, the plate load resistor is shunted by the 0.005-μf capacitor (C_{17}) and the 0.02-μf capacitor (C_{18}) in series, and the high frequencies are attenuated. When the arm of the potentiometer is at the cathode end, the cathode resistor is bypassed by the 0.02-μf capacitor. This bypass is effective only at the higher audio frequencies and reduces the degeneration in the stage thereby increasing the gain and giving treble boost.

(Continued on Page 4, Column 1)

WIRING DETAILS OF THE AMPLIFIER



A bottom view of the amplifier showing how components are located to obtain maximum fidelity and minimum distortion and hum.

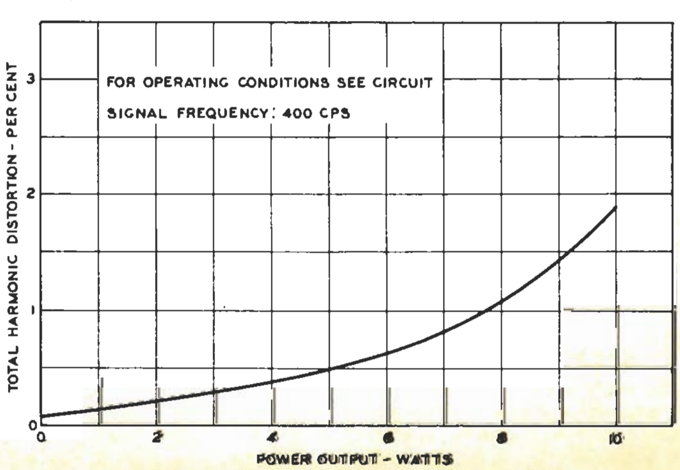
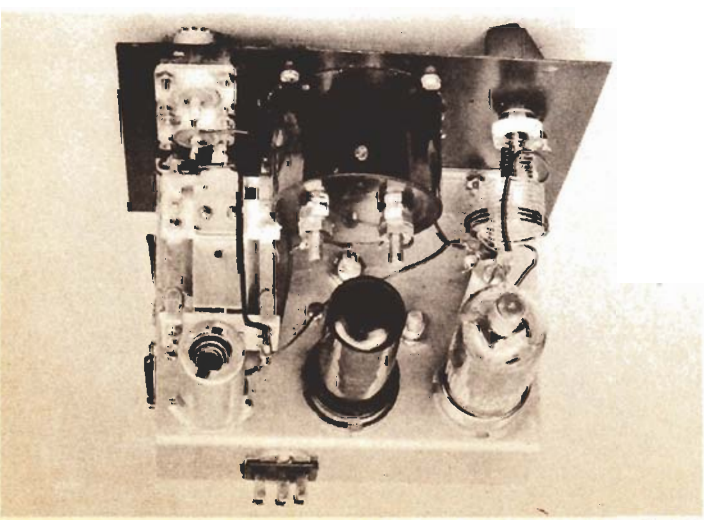


Figure 3. Total distortion versus power output.

UP AND OVER



Tubes and relay are mounted with room to spare on small 4" x 5" x 6" chassis. The 2E26 tube and tank circuit are shown on the upper right portion of the photo.

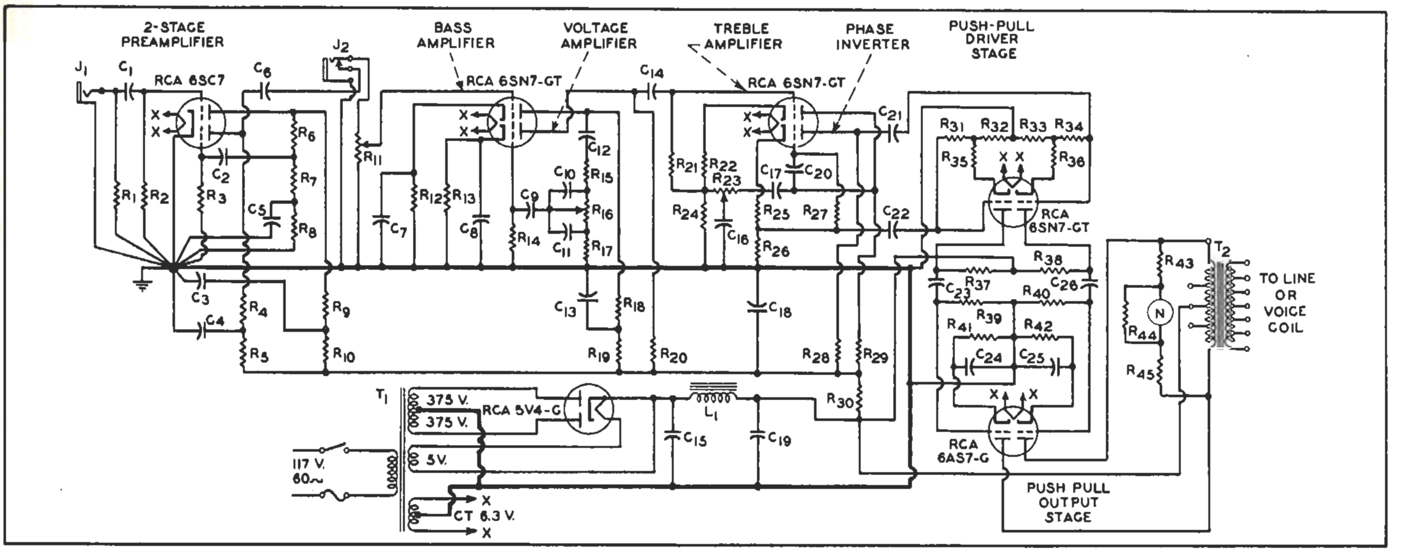


Figure 4. Schematic of the high fidelity amplifier.

AUDIO AMPLIFIER

(Continued from Page 3, Column 4)

The bass tone-control network is inserted between the two units of the first 6SN7-GT. It is located in an early stage to avoid boosting any hum voltages produced in any of the later amplifier stages. When the arm of the potentiometer is all the way down, the 0.03-μf capacitor (C_{11}) is shorted out, and bass attenuation is provided by the 0.01-μf capacitor (C_{10}) which limits the transmission of the low frequencies. When the arm of the potentiometer is at the plate end, the 0.01-μf capacitor is shorted out, and the 0.03-μf capacitor serves to increase at low frequencies the output of the voltage divider made up of the 100,000-ohm resistor, (R_{15}), the 0.03-μf capacitor (C_{11}), and the 10,000-ohm resistor (R_{17}). This arrangement provides bass boost.

The circuit constants are so chosen that the tone controls have negligible effect on the output at about 800 cycles. At 60 cycles a boost of 13 db or an attenuation of 12 db is possible. At 6000 cycles a boost of about 10 db or an attenuation of about 11 db is possible. Flat response is provided by intermediate adjustment of the controls. The over-all response of the amplifier for maximum and minimum adjustment of the bass and treble controls is shown in the curves of Figure 5.

Phonograph Pickup

The amplifier can be driven to full output with a signal of about 0.6 volt RMS at the volume control. The RCA 211X1 Magic Tone Cell crystal pickup has an output of about 1.5 volts and is excellent for use with this amplifier. This pickup gives high-quality reproduction and does not ordinarily require compensation.

If it is desired to use one of the low-output magnetic-type pickups, a pre-amplifier is required. The preamplifier circuit shown in the schematic, Figure 4, will provide the necessary gain and proper equalization for this type of pickup. A rubber shock-mounted tube socket should be used for the 6SC7 to minimize microphonic disturbances.

Hum

In order to obtain satisfactory performance from any high-fidelity amplifier, precautions must be taken to keep hum to an absolute minimum. In this amplifier, hum is kept down by observing the following precautions which serve to prevent minute voltage drops caused by high currents in the power supply or high-level stages from flowing through a ground circuit which is common to that used in the low level stages. Ground returns are made through a bus and not through the chassis. The electrolytic capacitors in the power supply are not grounded to the chassis but are mounted on insulating washers. The B- or ground bus is run from the center tap of the power transformer to the negative side of the electrolytics and then to the power output stage, the driver stage, and back through the early stages of the unit, picking up the ground returns in succession. The ground bus is finally tied to the chassis near the input jack. The hum output of the amplifier as constructed does not exceed 10 microwatts at the full output level.

PARTS LIST

C_1, C_2 = .05 μf
C_3, C_4 = 20 μf, electrolytic, 450 W.V.
C_5, C_9, C_{10} = 0.01 μf
C_6, C_{16}, C_{20}, C_{21}, C_{22}, C_{23}, C_{26} = 0.02 μf
C_7, C_8 = 25 μf, electrolytic, 50 W.V.
C_{11} = 0.03 μf
C_{12} = 0.01 μf
C_{13} = 8 μf, electrolytic, 450 W.V.
C_{14}, C_{17} = 0.005 μf
C_{15}, C_{19} = 15 μf, electrolytic, 450 W.V.
C_{18} = 10 μf, electrolytic, 450 W.V.
C_{24}, C_{25} = 20 μf, electrolytic, 150 W.V.
T_1 = 375-0-375, 160 ma., Thordarson —T22R33
T_2 = Output transformer, UTC-CG-16, plate to plate load 5000 ohms
L_1 = 12 h, 150 ma., Thordarson T17C00-B
J_1 = Phone jack
J_2 = Closed circuit—phone jack
N = ¼ watt neon lamp
R_1 = 5,600 ohms
R_2, R_3 = 3.3 Megohms
R_4, R_5, R_{29} = 33,000 ohms
R_6 = 200,000 ohms
R_7 = 27,000 ohms
R_8 = 180,000 ohms
R_9, R_{10} = 68,000 ohms
R_{11} = 0.5 Megohm, Potentiometer
R_{12}, R_{13}, R_{22} = 1,500 ohms
R_{14}, R_{21}, R_{27}, R_{31}, R_{34}, R_{39}, R_{40} = 0.5 Megohm
R_{15}, R_{43}, R_{45} = 100,000 ohms
R_{16} = 1 Megohm Potentiometer
R_{17}, R_{24} = 10,000 ohms
R_{18}, R_{20}, R_{26}, R_{28}, R_{37}, R_{38} = 47,000 ohms
R_{19} = 20,000 ohms
R_{23} = 0.25 Megohm, Potentiometer
R_{25} = 4,700 ohms
R_{30} = 10,000 ohms, 2 watts
R_{32}, R_{33}, R_{35}, R_{36} = 2,700 ohms
R_{41}, R_{42} = 2,500 ohms, 10 watts—wire wound
R_{44} = 75,000 ohms
All capacitors are 600 volts paper unless otherwise specified.
All resistors are ½ watt unless otherwise specified.

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J. H. OWENS, W2FTW .... *Editor*
H. S. STAMM, W2WCT .... *Associate Editor*

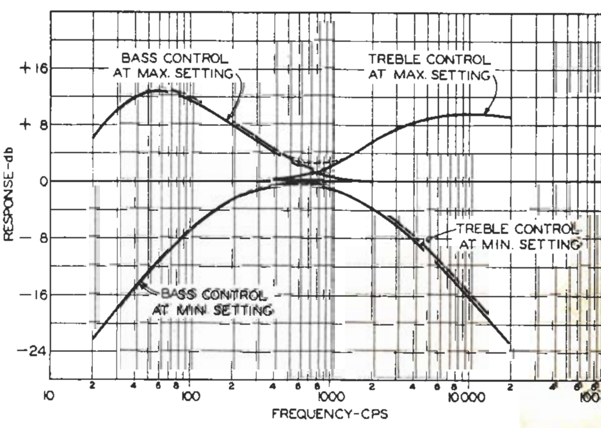

Figure 5. Over-all response of the amplifier for maximum and minimum adjustment of bass and treble controls.

RCA Ham Tips

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VOLUME VIII, No. 4 EDITORIAL OFFICES, RCA, HARRISON, N. J. NOVEMBER—DECEMBER 1948

NEW PRACTICAL METHOD DEVELOPED FOR CURING TVI!

Holiday Greetings . . .

our sincere wishes for you . . .

good health, much happiness

and abundant dx

REDUCING THE HARMONIC POWER OUTPUT OF AMATEUR TRANSMITTERS

By JOHN L. REINARTZ, W3RB
RCA Tube Department

Although it is not generally realized, most amateur transmitters using but one tuned circuit in the final output stage cannot meet the FCC rule stated in Article 17, Act of 1947 with regard to the reduction of the radiation of harmonic frequencies to not less than 40 db below the output of the fundamental frequency.

This article is the first of a series on harmonic reduction which will present some practical methods of minimizing TVI at the source.

Why We Have Harmonics

All tubes generate harmonic components when operated under class C conditions. Each time the grid of the tube is driven positive, a current pulse flows in the plate circuit of the tube. The current value for each of the harmonics produced depends on the angle of plate-current flow. For example, for a plate-current-flow angle of 140° the the harmonic relationships[1] are given in Table I.

TABLE I

Component	Current, % of Fundamental	Equivalent Power level referred to Fundamental (db)
Fundamental	100	0
Second Harmonic	69.4	— 3.2
Third Harmonic	30.8	—10.3
Fourth Harmonic	4.6	—25.8

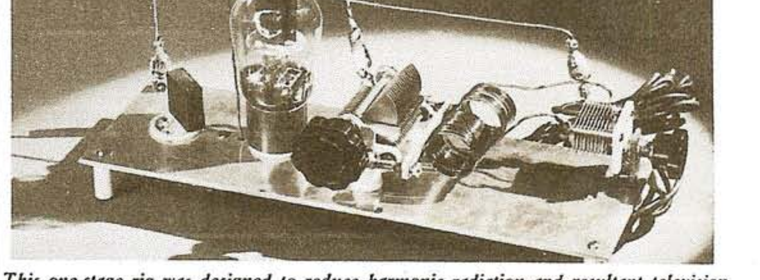
The voltages produced across the output circuit by these harmonic components are dependent on the magnitude of the impedances presented to each harmonic component by the tuned circuit and are dependent to a large degree on the Q of the tuned circuit.

The performance of any amplifier in a transmitter is determined by both the characteristics of the associated tuned circuit and the tube. The choice of the tube has been made easy for us by the manufacturer who has supplied us with the necessary tube characteristics and operating values. It is, therefore, only necessary to consider the rf circuit constants that should be used. C, L, and R can be of various values within rather large limits, and, if frequency were the only consideration, the capacitance could be made small and the inductance large or vice versa. The action of the reflected load resistance on the tuned tank circuit is to decrease the sharpness of tuning as its shunt value is made smaller. In actual practice, however, there is a compromise value for the three components which results in high efficiency and good harmonic suppression.

Now, the larger the value of the tuning capacitor, the smaller the

(Continued on Page 2, Column 1)

EXPERIMENTAL MODEL



This one-stage rig was designed to reduce harmonic radiation and resultant television interference. Although it is not the unit described in HAM TIPS, it utilizes the same practical method discussed.

SIMPLIFYING THE CALCULATION OF TRANSMITTING TRIODE PERFORMANCE

By E. E. SPITZER
Power Tube Group
RCA Engineering Section

Simple methods of calculating transmitting triode performance are presented in this article which give results very close to published data. They are applicable to class C amplifiers both modulated and unmodulated and also to class B audio amplifiers.

Published data on transmitting tubes show many typical operating conditions which are excellent guides for the operation of the tubes. Conditions sometimes arise, however, which make other operating conditions desirable or necessary.

Many amateurs would probably like to calculate new tube operating conditions but are deterred by the apparently formidable mathematics involved. In this article, the mathematics for the calculations of class C amplifiers are very much boiled down by eliminating one variable, the length of the plate-current pulse. For our calculations, this variable is assumed to be 140 degrees of an rf cycle. 140 degrees is a representative value for class C amplifiers. With this assumption, five simple formulas permit calculation of power output, plate loss, grid bias, grid current, and driving power.[1] The same method of calculation is extended to class B audio amplifiers by using a plate pulse of 180°. Several examples are worked out to show clearly how the methods are used.

In the method described here, the calculations are based on the instantaneous values of grid and plate current at the peak of the plate-current pulse. It is well known that this peak occurs when the grid voltage is at its peak positive excursion and the plate voltage is at its peak negative excursion. When these two voltages are equal, the tube has very nearly its optimum performance. This important fact is recognized in the tube characteristic curves by the inclusion of a curve labeled $E_c = E_b$. The 812-A characteristic curves shown in Figure 5 include this limiting curve. If we choose a point such as "A" on the $E_b = E_c$ curve in Figure 5, we can read directly the instantaneous plate current, the required plate and grid voltages, and then, by dropping down to point "B" on the I_c family, we can also read the instantaneous grid current for the same grid voltage. All calculations are then made using these values.

Class C Operation (Telegraphy and Telephony)

It is assumed that we have data on the tube including the plate-characteristics curves. It is also assumed that we want to operate at a certain value of dc plate voltage,

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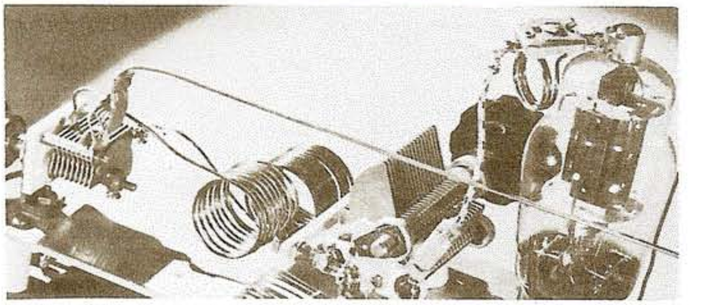
WHAT THE DOCTOR ORDERED



Component details which were found essential for reducing harmonic output are shown in this close-up. A plate shunt trap in upper right of photo reduces harmonic pulses generated at the plate of the 807. An absorption trap coil, center, tunes to the harmonic and changes the phase relation with respect to the plate tank tuning system. Cancellation of stray harmonic currents traversing the chassis is accomplished by means of a cancellation wire shown running parallel with chassis.

HARMONIC POWER OUTPUT

(Continued from Page 1, Column 4)

impedance it presents to the harmonic components in the plate-current pulse. Consequently, the harmonic voltage produced across this capacitor is smaller. In addition, there is a larger circulating current in a larger capacitance for a given power output. It is this ratio, called Q, of the circulating volt-amperes, (rf voltage times circulating current) to the power output, that determines the harmonic power that can be passed on. The harmonic power is higher for low Q and lower for high-Q circuits.

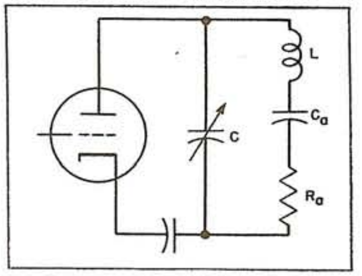


Figure 1. A single-tuned circuit.

Harmonics are suppressed to a considerable extent even by a simple tuned circuit.[2] For example, if the tuned tank circuit is as shown in Figure 1 where R_a and C_a are the antenna resistance and capacitance, then the db reduction of harmonics in the antenna due to the Q of the tank circuit is given in Table II.

TABLE II

HARMONIC REDUCTION in db DUE TO A SINGLE-TUNED CIRCUIT REFERRED TO FUNDAMENTAL-FREQUENCY POWER

Q	Second Harmonic	Third Harmonic	Fourth Harmonic
5	−23.5	−32.0	−37.5
10	−29.6	−38.1	−43.5
15	−33.0	−41.6	−47.0
20	−35.6	−44.1	−49.6

adding these values to those given in Table I gives—

TABLE III

HARMONIC POWER OUTPUT in db OF TUBE AND SINGLE-TUNED CIRCUIT REFERRED TO FUNDAMENTAL-FREQUENCY POWER

Q	Second Harmonic	Third Harmonic	Fourth Harmonic
5	−26.7	−42.3	−63.3
10	−32.8	−48.4	−69.3
15	−36.2	−51.9	−72.8
20	−38.8	−54.4	−75.4

We see from these tabulations that every time we double the Q of the tuned circuit the harmonic level goes down by 6 db. For the second harmonic, however, this reduction is still insufficient to comply with the FCC rule of −40 db even when the Q of the tuned circuit is 20.

Harmonic Suppression in Double-tuned Circuit

If the circuit is doubly tuned as in Figure 2, there is an even greater reduction in harmonics as shown in Table IV.

TABLE IV

HARMONIC REDUCTION in db DUE TO 2 COUPLED CIRCUITS REFERRED TO FUNDAMENTAL-FREQUENCY POWER

Q	Second Harmonic	Third Harmonic	Fourth Harmonic
5	−38.2	−54.4	− 76.8
10	−50.2	−67.4	− 88.8
15	−57.3	−75.1	− 96.2
20	−62.3	−79.4	−100.8

It can be seen from this tabulation that whenever the value of Q is doubled the harmonics are all reduced by 12 db. Another important fact that can be deduced from these tables is that it is better to have a Q of say 10 in each tuned circuit of Figure 2 than to have a Q of 20 in the single tuned circuit of Figure 1. Now we can meet the FCC rule of −40 db for harmonic radiation if we use a Q of 10 or better in each of the tuned circuits. This −40-db value represents 0.01 watt for an amateur station radiating 100 watts at the fundamental frequency.

Field-Strength Considerations

Let us consider the field strength produced by an antenna. The field strength produced by a horizontal half-wave dipole[3] is

$$E = 23\ \frac{\sqrt{P}}{d} \text{ volts per meter,}$$

where P is the radiated power in watts and d is the distance in feet from the radiator to the point where E is measured. This value can be considered an average value. Actually, the field strength varies with distance between a lower and higher value because of subtraction and addition of the wave reflected from the ground and the direct wave, and also because the configuration of the lobes changes with the effective length of the transmitting antenna for any particular harmonic. The formula is useful for distances up to about 650 feet. Since the amateur is concerned with distances within this value down to say 50 feet, the above formula for field strength applies. Inversion of the formula will give the power required to produce a given field strength.

$$P = 1880\ (Ed)^2 \text{ microwatts,}$$

where E is in volts/meter and d is in feet.

The limiting field strength for the service area of a television transmitter is considered by the FCC to be 500 microvolts per meter in residential and rural areas. It has been determined that an interfering

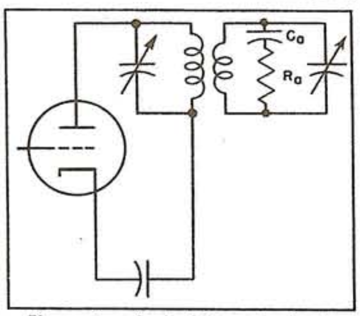


Figure 2. A double-tuned circuit.

signal of 1/100 this value is not objectionable. The amateur, therefore, should not produce an interfering field greater than 5 microvolts/meter for such a service area.

Let us now find the power required to produce such a field at 500 feet.

$P = 1880\ (5 \times 10^{-6} \times 500)^2 = 0.012$ microwatts.

Compare this 0.012-microwatt value with the 0.01 watt (10000 microwatts) which the present FCC rulings allow for harmonic radiation when the radiated fundamental output is 100 watts. A 0.01-microwatt value represents a power ratio of harmonic to fundamental values of 10^{-10} or —100 db when the power radiated at the fundamental is 100 watts. This changes to 10^{-11} or —110 db when the fundamental power is 1000 watts. These values are far more severe than the —40 db level currently required, but are what the amateur must attain if he wants to stay on good terms with the general public.

> **CURING TVI**
>
> *"Reduction of Harmonic Power Output in Amateur Transmitters" published in this issue of HAM TIPS is the first of a series of articles on this important subject by John L. Reinartz, W3RB, a member of the RCA Tube Department and one of the nation's best-known Radio Amateurs. In his next article Captain Reinartz will describe further his method of attack on TV interference.*

Other Methods of Reducing TVI

Because even two tuned tank circuits may fail to reduce an interfering signal to the −100 or −110 db level, other means must be found. Several good articles on the subject have appeared in amateur magazines. Mack Seybold has shown in the August 1947 issue of QST that the addition of trap circuits in the plate lead of the final class C stage will reduce the harmonic level some 40 to 50 db and if considered along with two tuned tank circuits may reach the desired −100 or −110 db level.

Harmonic Suppression

In cases where even the processes outlined above fail to reduce the interference to television reception at distances shorter than 500 feet, it will be found advantageous to resort to additional grounded trap circuits tuned to the interfering harmonic. These trap circuits should be closely coupled to the hot end of each plate tank circuit of every stage in the transmitter. Such a system, devised by the writer, was found capable of apparently completely cancelling a harmonic. Because every rf stage in a transmitter amplifies the harmonic components present in its grid ex-

(Continued on Page 3, Column 3)

IN DOUBLER SERVICE EMISSION COUNTS

It takes a lot of cathode emission to back up heavy peak plate current pulses when driving a frequency-multiplier tube for optimum gain. That's why RCA high-transconductance beam power tubes are preferred types for medium-power doubler and tripler service. They produce maximum plate-current swing for a given grid signal voltage. And they have the high-power filaments and heater-cathodes required to handle high peak plate-current . . . with emission to spare.

SIMPLIFIED CALCULATIONS

(Continued from Page 1, Column 2)

E_b, and with a certain average plate current, I_b. We want to know power output, P_o, grid bias, E_c, dc grid current, I_c, and driving power, P_d.

First we find the peak plate current. This value is 4 times the average plate current, I_b. Then, we go to the plate-characteristics curves and on the curve $E_c = E_b$, we find the instantaneous plate voltage e_b, and the instantaneous grid voltage e_c, at which we get the plate current of 4 I_b. With these values, together with the amplification factor, μ, obtained from the tube data, we then apply the following formulas.

Power output

$$P_o = 0.86\ (E_b - e_b)\ I_b\ \text{(watts)} \qquad (1)$$

Plate loss

$$P_p = E_b\ I_b - P_o\ \text{(watts)} \qquad (2)$$

Grid bias

$$E_c = \left[\frac{E_b}{\mu} + 0.52\,\frac{(\mu + 1)}{(\ \mu\ )}\,e_b\right]\text{(volts)} \qquad (3)$$

Peak rf driving voltage

$$e_g = E_c + e_c\ \text{(volts)} \qquad (4)$$

To get the dc grid current, I_c, we first have to calculate $\frac{E_c}{e_g}$ the ratio of the grid bias to the peak rf driving voltage and then from Figure 4 get $\frac{I_c}{i_c}$ the ratio of average grid current to the instantaneous grid current at $E_c = E_b$. The instantaneous grid current is obtained from the characteristic curves.

Then, the average grid current,

$$I_c = i_c \times \left(\text{ratio } \frac{I_c}{i_c} \text{ from Figure 4}\right),\ \text{(amperes)} \qquad (5)$$

and driving power

$$P_d = 0.9 \times e_g \times I_c\ \text{(watts)} \qquad (6)$$

The calculated power output figure as well as the published typical power output values are theoretical values of tube output which include both useful output and rf losses in the tube, in the tank circuit, and associated wiring. Useful rf power obtainable, therefore, will depend on the efficiency of the circuit and in turn upon the quality of components and circuit layout used.

The calculated value of driving power includes only the actual power input to the grid plus the power lost in the bias supply. It

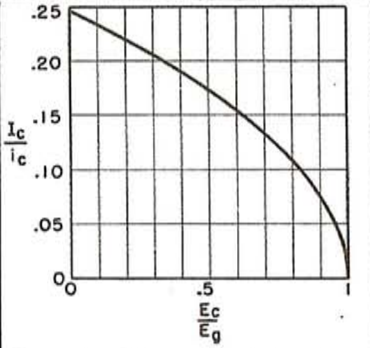


Figure 4. Curve from which ratio of $\frac{I_c}{i_c}$ is obtained.

does not include rf losses that occur in the driver-stage tank circuit, in coupling from the driver stage, in the socket and wiring or losses in tubes caused by transit-time loading. The driver stage power output, therefore, should be substantially greater than the calculated value of driving power in order to provide an adequate range of adjustment for optimum transmitter performance.

Example

As a check, this method may be applied to the 1500-volt ICAS Telegraphy condition given in the published data for the 812-A (Figure 6 on page 4). The given conditions are $E_b = 1500$ volts, $I_b = 173$ Ma., $\mu = 29$. The peak plate current is $4 \times 173 = 692$ ma. This value of current can be obtained at $e_c = e_b = 120$ volts, as given in the plate characteristics, Figure 5, at point A.

Power output

$$P_o = 0.86\ (1500 - 120)\ 0.173 = 205 \text{ watts}$$

Plate loss $P_p = 1500 \times 0.173 - 205 = 259 - 205 = 54$ watts

Grid bias

$$E_c = -\left[\frac{1500}{29} + 0.52\,\frac{(30)}{(29)}\,120\right] = -116 \text{ volts}$$

Peak rf driving voltage

$$e_g = 116 + 120 = 236 \text{ volts}$$

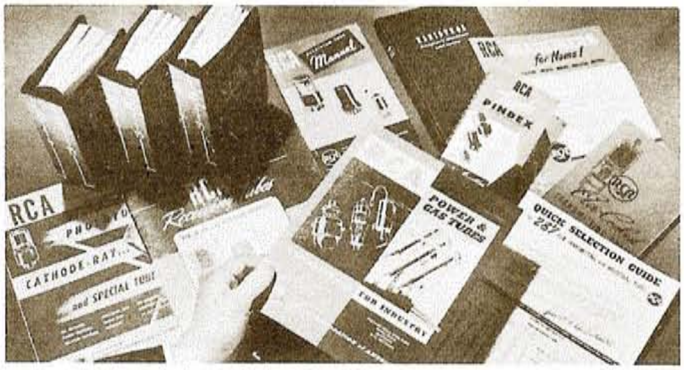
$$\text{and } \frac{E_c}{e_g} = \frac{116}{236} = 0.49$$

$$\text{From Figure 4, } \frac{I_c}{i_c} = 0.175$$

From the characteristic curves (Figure 5) for $e_c = e_b = 120$ volts, $i_c = 220$ ma. or 0.220 amp. at point "B".

(Continued on Page 4, Column 1)

FOUNTAINHEAD OF TUBE INFORMATION



Amateurs everywhere look to RCA tube publications for accurate data and unquestioned authoritativeness. For information on the material shown, see your local RCA Distributor, or write Commercial Engineering, RCA, Harrison, N. J.

HARMONIC POWER OUTPUT

(Continued from Page 2, Column 4)

citation voltage, the first place to get rid of the harmonic is at the crystal oscillator plate-tank circuit. What may be left can be taken care of in subsequent stages at their respective plate tank circuits.

To prove the effectiveness of this system, a 2E26 oscillator-doubler, controlled by a 7-Mc crystal, followed by an 813 final was built having the shunt traps roughly tuned to 28 Mc and the grounded traps (tuned to the offending harmonic, approx. 28 Mc) coupled closely to each plate tank circuit.

In some cases, it may be necessary to tune one or more of these traps to the third harmonic, to obtain greater reduction of interference.

The essentials of this circuit are shown in Figure 3. A television receiver was set up ten feet away and connected to a standard 90" folded-dipole antenna through 100" of 300-ohm, twin-lead transmission line. The antenna for the transmitter was strung within 8 feet of the TVR antenna. With normal excitation to the 813 tube in the 20-meter band and with the TVR tuned to channel 2, it was possible to operate the transmitter with 100% 60-cycle modulation without undue interference to the TVR even though the transmitter was incompletely shielded in that the entire top cover of the transmitter cabinet was removed. The measured output from the 813 was adjusted to 150 watts as a convenient value for testing purposes.

A cathode-ray oscilloscope was connected to the grid circuit of the receiver kinescope to allow further visual indication of the interference caused by the transmitter when the closely coupled grounded-trap circuits were detuned. Under such conditions the pattern on the kinescope was a maze of interference and the CRO tube showed a pattern with both rf and 60-cycle components present at the grid of the kinescope. All these patterns disappeared when the grounded plate traps were properly tuned. The shunt traps in series with the plate circuits of the two tubes needed only to be tuned to the inductive side of resonance of the unwanted harmonic. This tuning was not critical. To obtain the results described, the grounded-trap coil should be located at the hot end of the tank coil and wound on the same form and in the same direction. Ground the trap coil at the far end, away from the tank coil.

It is realized that a complete test requires that the TVR be tuned to a television station signal in order to determine if any interference may still be present that could not be detected under the test conditions outlined above. Such tests are under way and will be discussed in the next article of this series.

[1] Radio Engineers Handbook, FE Terman, Fig. 86

[2] "L-bus and Reder", Proc. IRE., Vol. 19, pp 949-962, 1931

[3] RMA publication R4-2860-A (July 1948) by W. T. Wintringham.

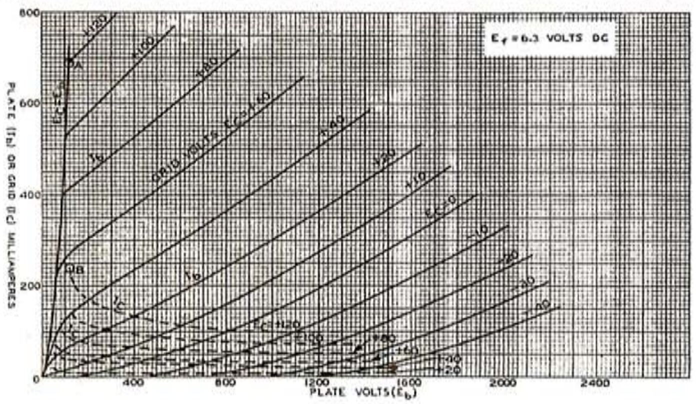


Figure 5. The 812-A characteristic curves.

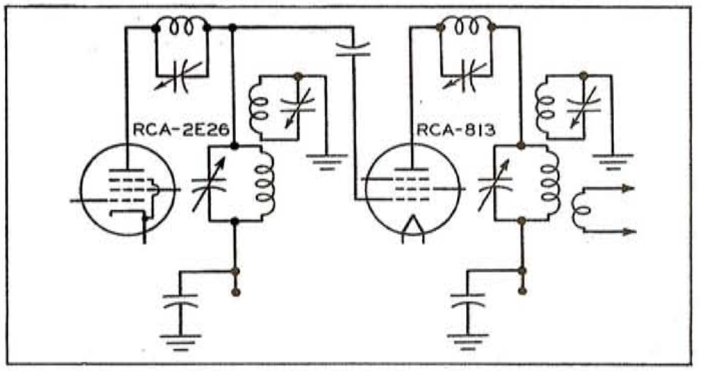


Figure 3. Schematic of method devised to cancel transmitter harmonics.

AF POWER AMPLIFIER & MODULATOR—Class B

Maximum Ratings, *Absolute Values:*

	CCS	*ICAS*	
DC PLATE VOLTAGE	1250 max.	1500 max.	volts
MAX.-SIGNAL DC PLATE CURRENT*	175 max.	175 max.	ma
MAX.-SIGNAL DC PLATE INPUT*	165 max.	235 max.	watts
PLATE DISSIPATION*	45 max.	65 max.	watts

Typical Operation:

Values are for 2 tubes

DC Plate Voltage	1250	1500	volts
DC Grid Voltage#	−40	−48	volts
Peak AF Grid-to-Grid Voltage	225	270	volts
Zero-Signal DC Plate Current	22	28	ma
Max.-Signal DC Plate Current	260	310	ma
Effective Load Resistance (plate-to-plate)	12200	13200	ohms
Max.-Signal Driving Power (Approx.)	3.5	5	watts
Max.-Signal Power Output (Approx.)	235	340	watts

PLATE-MODULATED RF POWER AMP.—Class C Telephony

Carrier conditions per tube for use with a max. modulation factor of 1.0

Maximum Ratings, *Absolute Values:*

	CCS	*ICAS*	
DC PLATE VOLTAGE	1000 max.	1250 max.	volts
DC GRID VOLTAGE	−200 max.	−200 max.	volts
DC PLATE CURRENT	125 max.	150 max.	ma
DC GRID CURRENT	35 max.	35 max.	ma
PLATE INPUT	115 max.	175 max.	watts
PLATE DISSIPATION	30 max.	45 max.	watts

Typical Operation:

DC Plate Voltage	1000	1250	volts
DC Grid Voltage	−110	−115	volts
From a grid resistor of	3400	3300	ohms
Peak RF Grid Voltage	220	240	volts
DC Plate Current	115	140	ma
DC Grid Current (Approx.)	33	35	ma
Driving Power (Approx.)	6.6	7.6	watts
Power Output (Approx.)	85	130	watts

RF POWER AMPLIFIER & OSC.—Class C Telegraphy

Key-down conditions per tube without modulation ##

Maximum Ratings, *Absolute Values:*

	CCS	*ICAS*	
DC PLATE VOLTAGE	1250 max.	1500 max.	volts
DC GRID VOLTAGE	−200 max.	−200 max.	volts
DC PLATE CURRENT	175 max.	175 max.	ma
DC GRID CURRENT	35 max.	35 max.	ma
PLATE INPUT	175 max.	260 max.	watts
PLATE DISSIPATION	45 max.	65 max.	watts

Typical Operation:

DC Plate Voltage	1250	1500	volts
DC Grid Voltage:			
From a fixed supply of	−90	−120	volts
From a grid resistor of	3000	4000	ohms
From a cathode resistor of	530	590	ohms
Peak RF Grid Voltage	200	240	volts
DC Plate Current	140	173	ma
DC Grid Current (Approx.)	30	30	ma
Driving Power (Approx.)	5.4	6.5	watts
Power Output (Approx.)	130	190	watts

* *Averaged over any audio-frequency cycle of sine-wave form.*

\# *Grid voltages are given with respect to the mid-point of filament operated on ac. If dc is used, each stated value of grid voltage should be reduced by one-half the filament voltage and the circuit returns made to the negative end of the filament.*

\#\# *Modulation essentially negative may be used if the positive peak of the audio-frequency envelope does not exceed 115% of the carrier conditions.*

Figure 6. General data for the 812-A.

SIMPLIFIED CALCULATIONS

(Continued from Page 3, Column 2)

Therefore, the average grid current

$I_c = 0.220 \times 0.175 = 0.038$ amperes

and the driving power

$P_d = 0.9 \times 236 \times 0.038 = 8.0$ watts

A comparison between these calculated values and the published data for the 812-A is shown in Table 1 below.

It can be seen from this comparison that for practical purposes there is a satisfactory agreement between published and calculated values.

Class B Operation (Audio Frequency)

For class B audio operation it may be assumed E_b and I_b are given. In this case, I_b is the plate current for both tubes of the push-pull amplifier.

Then, peak plate current for two tubes $i_b = 1.57\ I_b$ (7)

At the value of i_b given by (7) we determine the peak grid voltage e_c and the peak plate voltage e_b on the $E_c = E_b$ curve.

The following formulas apply:

Power output for two tubes,
$P_o = 0.78\ (E_b - e_b)\ I_b$ (watts) (8)

Plate loss per tube,
$P_p = \frac{1}{2}(E_b\ I_b - P_o)$ (watts) (9)

The grid bias should be chosen so that at E_b, a zero-signal current flows which produces a plate dissipation of about ⅓ the rated dissipation. Thus, if each tube is rated to dissipate P_p' watts,

Zero-signal plate current for two

tubes $= I_b' = \frac{2P_p'}{3E_b}$ (amperes) (10)

TABLE 1. (class C)

	Calculated Values	Published Data
DC Plate Voltage (E_b)	1500	1500 volts
DC Grid Voltage (E_c)	−116	−120 volts
Peak RF Grid Voltage (e_g)	236	240 volts
DC Plate Current (I_b)	173	173 ma.
DC Grid Current (I_c)	38	30 ma.
Driving Power (P_d)	8.0	6.5 watts
Power Output (P_o)	205	190 watts

The bias required for this plate current can be found from the characteristic curves. The peak grid drive per tube is then the sum of the bias and e_c ($= e_b$) which was determined for equation (8).

Peak grid-to-grid driving voltage

$= e_g = 2(e_c + E_c)$ (volts) (11)

The required plate-to-plate load resistance

$R_L = \frac{2.6\ (E_b - e_b)}{I_b}$ (ohms) (12)

The maximum-signal driving power for two tubes,

$W_d = \frac{i_c\ e_g}{4}$ (watts) (13)

where i_c is the grid current in amperes at the point found for equation (8).

Example

Again consider the typical operating conditions given in the published data for the 812-A as a class B AF power amplifier in ICAS service. The data given are $E_b = 1500$V, $I_b = 310$ ma. or 0.310 amperes (2 tubes).

Then the peak plate current $i_b = 1.57 \times 310 = 487$ ma.

From the $E_c = E_b$ curve in Figure 5 we get 487 ma. at $e_c = 90$ volts and $e_b = 90$ volts.

Then from equations (8), (9), and (10), power output for two tubes $P_o = 0.78\ (1500 - 90)\ 0.310 = 340$ watts. Plate loss per tube $P_p = \frac{1}{2}(1500 \times 0.310 - 340) = 62.5$ watts. Zero-signal plate current for two tubes

$I_b' = \frac{2 \times 65}{3 \times 1500} = 0.029$ amperes.

The required bias for a plate current (per tube) of 14.5 ma. at 1500 volts can be found from Figure 5 and is about −48 volts.

Then from equation (11),

Peak grid-to-grid driving voltage
$e_g = 2(90 + 48) = 276$ volts.

From equation (12), plate-to-plate load resistance $R_L =$

$\frac{2.6 \times (1500 - 90)}{0.310} = 11{,}800$ ohms

To get the driving power, we first need the peak grid current at $e_c = e_b = 90$ volts. This value is obtained from Figure 5 and is 130 ma. or 0.130 amperes. Then, driving power for two tubes

$P_d = \frac{0.130 \times 276}{4} = 9$ watts.

The calculated values may now be compared with the 812-A published data, as shown in Table 2 below.

Again, the approximate calculations give results in good agreement with the published data.

[1]For a derivation of these formulas, refer to "Simplified Methods for Computing Performance of Transmitting Tubes", W. G. Wagener, Proc. IRE., Vol. 25, No. 1, January 1937, pp 47-77.

TABLE 2. (class B audio)

	Calculated Values	Published Data
DC Plate Voltage (E_b)	1500	1500 volts
DC Grid Voltage (E_c)	−48	−48 volts
Peak AF Grid-to-Grid Voltage (e_g)	276	270 volts
Zero-Signal DC Plate Current (I_b')	29	28 ma.
Max.-Signal DC Plate Current (I_b)	310	310 ma.
Effective Load Resistance (Plate to Plate) (R_L)	11,800	13,200 ohms
Max.-Signal Driving Power (P_d)	9	5 watts
Max.-Signal Power Output (P_o)	340	340 watts

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A PRACTICAL METHOD FOR REDUCING HARMONIC RADIATION

USING TUNED FEEDBACK CIRCUITS TO CANCEL TRANSMITTER HARMONICS

By JOHN L. REINARTZ, W3RB
RCA Tube Department

In the previous article on this subject it was pointed out that the generation of Harmonics in a class C stage is natural and must be expected. In fact, it is this harmonic generation that makes doubler and tripler stages possible. However, if the radiated power capable of causing interference must be kept to less than 0.01 microwatt, even such high order harmonics as the 8th or 16th from fundamental operation at 7 or 3.5 Mc may cause television interference. Even more trouble can be expected from stages operating at 14 and 28 Mc where the harmonic order that can cause interference is much lower and the amplitude much higher. The problem then is —what to do about these harmonic radiations that cause TVI.

What To Do About It

In Part I, it was pointed out that previous investigators advocated the use of complete shielding along with the installation of parallel-tuned series-inserted traps [1] and other bypassing devices which must also be shielded. The writer, however, has had considerable success with another method of reducing harmonic radiation which does not depend upon shielding for its efficacy. This method involves the use of the tank-coil traps described in Part I but with one additional and important refinement in the method of connecting the traps together and grounding them. These tank-coil traps operate by absorbing the unwanted harmonics and cancelling them out by means of tuned feedback circuits. But more of this later. Our first problem is to locate the offending harmonics.

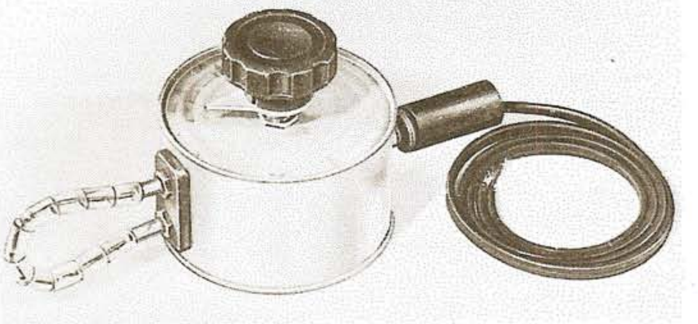
Locating the Harmonic

In order to use this method, we must first locate the offending harmonic and utilize some method of measuring its relative amplitude. For this purpose an old standby, the universally used absorption-type wavemeter, comes into play.

A modified wavemeter that has proved extremely sensitive was devised by the writer. This unit, diagrammed in Figure 1, consists of a resonant circuit (L_1C_1) for the frequencies under discussion, a 4-turn ¼" diameter coil of #20 enamelled insulated wire (L_2) in series with the resonant circuit, a 1N34

(Continued on Page 2, Column 1)

"TIN-CAN" WAVEMETER



Despite its humble origin, this easily built but extremely sensitive absorption type wavemeter is a "must" for tracking down offending harmonic radiation in transmitters.

SELF-CONTAINED VFO DESIGNED FOR STABILITY ON ALL BANDS

By ANDREW RAU, JR., W3KBZ
RCA Tube Department

Even a confirmed proponent of crystal-controlled operation will concede that under present-day crowded band conditions, a really stable variable-frequency oscillator is indispensable. The completely self-contained VFO described in this article includes a regulated power supply, provision for oscillator keying, band spread on the higher-frequency bands, control circuits for the receiver and transmitter, and coupling by means of coaxial cable to the crystal socket of the transmitter. This method of coupling permits locating the high-power rf section away from the operating position.

A really satisfactory VFO has two basic requirements. The first of these requirements is relative freedom from drift or instability, and the second is the ability to key without chirps or other transient effects. A careful choice of components with due consideration to layout, along with a "workmanlike" mechanical job will go a long way toward meeting the first requirement. The recently publicized Clapp circuit [1] will assist in satisfying the second requirement.

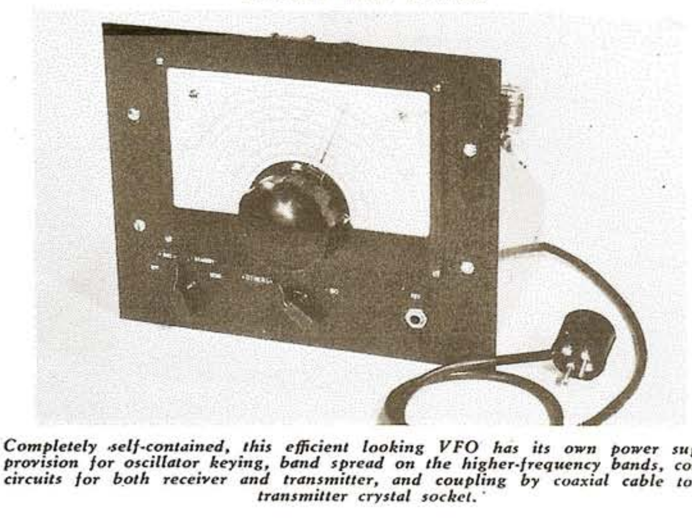
Frequency Drift Considerations

In addition to the effects of component choice, layout, and workmanship, the most troublesome factors contributing to the instability of a self-excited oscillator are the effects of humidity, temperature, and changes in operating conditions such as voltages, currents, etc. The effect of humidity can be minimized by the use of high-quality components of ceramic or other low-loss material in the rf portions of the circuit. The effects of temperature are most satisfactorily minimized through the use of a frequency-determining coil wound on a ceramic form large enough to give a high "Q" but which will undergo little change of inductance with temperature. In addition, the main tuning capacitor should be of sturdy construction with small plates well spaced in a frame with ceramic end plates and with two bearings. All other capacitors should be silver mica or ceramic types with a low temperature coefficient.

Because fundamentally it is desirable to obtain maximum "Q" in the oscillator tank circuit, it is important to make all rf connections in this circuit as short and direct as possible. Moreover, it is undesirable to depend on a steel chassis to conduct rf tank currents because

(Continued on Page 3, Column 2)

STURDY AND STABLE



Completely self-contained, this efficient looking VFO has its own power supply, provision for oscillator keying, band spread on the higher-frequency bands, control circuits for both receiver and transmitter, and coupling by coaxial cable to the transmitter crystal socket.

HARMONIC OUTPUT

(Continued from Page 1. Column 4)

crystal and microammeter in series connected across the 4-turn coil, and a capacitor (C_2) connected across the meter. The microammeter is connected to the tuned circuit by means of a flexible two-wire cord of any desired length. This arrangement allows the operator to get much closer to circuits suspected of harmonic radiation than would be the case if the resonant circuit and the meter were in one container. The absorption meter may be built into a small metal can into which the pick-up loop for the particular frequency

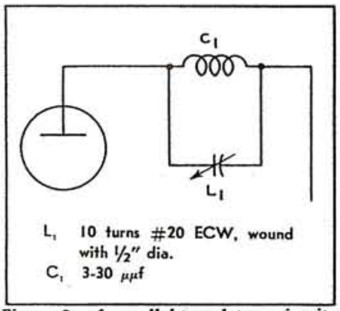


Figure 2. A parallel-tuned trap circuit.

range desired can be plugged. A photograph of the wavemeter is shown on Page 1. When a variable capacitor of 3.5 to 75 μμf is used together with a pickup loop 2" long, consisting of a single hairpin turn, the tuning range extends from 50 to 150 megacycles.

The hairpin pickup loop should be threaded with glass or porcelain beads or with some other insulating material so that when the wavemeter is used to probe near high-voltage points, direct contact will be prevented. An additional, but very worthwhile precaution is to connect a flexible grounding wire between the wavemeter can and ground.

Because the 4-turn coil is inside the can, it picks up very little energy from the fundamental frequency when the wavemeter hairpin is held close to a tank circuit.

Preliminary Checking

The next thing to do is to make a preliminary check with the wavemeter to determine which harmonics are prevalent in the transmitter and where they are most prominent. A good place to check is near the plate connection of each tube. Caution must be exercised when high-voltage points are checked in order to prevent any accidental contact.

As the check for harmonics progresses, make a note of the location and relative value of the harmonics for future reference. Don't be surprised if harmonic indications are noted in the heater leads of heater-cathode-type tubes or at that end of a plate-tuning-capacitor frame which is not bypassed for rf ground. In order to cut down the harmonics at these points, connect a bypass capacitor of 0.001 μf and the proper voltage rating between the plate-tuning-capacitor frame and ground. Between the heater lead and ground use a 0.01 μf capacitor. A further check with the wavemeter at these points will in all probability show a substantial reduction in the harmonic amplitude. Any long lead under a chassis may also show harmonic voltages and should be similarly bypassed at readily accessible points.

Tuned-Plate Traps

After adequate bypassing is accomplished, the first step is to insert parallel-tuned trap circuits in series with the plate leads of each class C stage. See Figure 2. These traps may be made readily with ten turns of #20 enamel coated wire, wound with a ½-inch inside diameter and shunted with a 3- to 30-μμf trimmer capacitor for tuning. It will be found that the tuning range of this trap extends from 25 to 80 Mc.

Tank-Coil Traps

The next step, which is something new in TVI reduction, is to utilize the previously mentioned tank-coil traps which absorb and cancel through negative feedback the unwanted frequencies. These traps are positioned about ¼" from the hot end of the plate tank coil at each stage. Each trap (see Figure 3) is made by winding a coil of as many turns as can be made from 18 inches of wire in the same direction and of the same diameter as the tank coil.

Wire comparable in size to that of the tank coil should be used although it is not necessary to use wire larger than #10. The coil is then shunted with a 3- to 50-μμf tuning capacitor. The hot end of the coil is connected to the stator plate. This capacitor is mounted adjacent to but not more than 2" to 3" from the coil in such a manner as to be tunable from the front panel by means of an extension shaft. The rotor side of the variable capacitor is then grounded. Similar traps are mounted at the

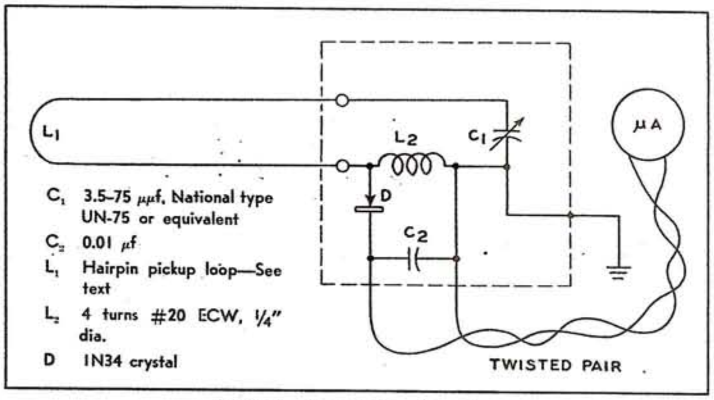


Figure 1. Wavemeter schematic.

hot ends of the other plate tanks and the antenna coil as shown in Figure 4. Each trap is then coupled by means of a 25-μμf fixed capacitor to a common line which is grounded at a point approximately half way between any pair of 25-μμf fixed capacitors.

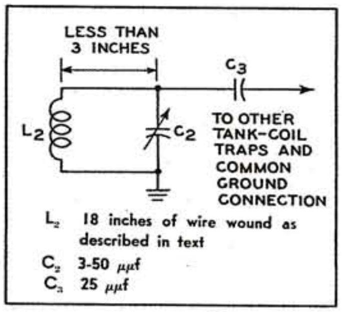


Figure 3. A tank-coil trap circuit.

Connecting the Grounding Wire

A final connection completes the hookup. This connection is made to the trap in the tank circuit of the final and consists of a grounding wire approximately ten inches long connected between the ungrounded side of the variable tuning capacitor and any convenient point on the chassis. Some experimentation may be necessary to locate the optimum grounding point necessary to produce maximum harmonic attenuation.

In push-pull stages only one tank-coil trap is required. If either a center-tapped antenna tuning unit or a split tank circuit is used, the tank-coil trap may be located at either end.

Shielding Considerations

Although the operation of this system of reducing harmonic interference does not specifically require shielding, it is advantageous to use a metal front panel in addition to the usual metal chassis. The metal front panel minimizes the detuning effects of hand and body capacitances when the several air capacitors are adjusted.

Tune Up

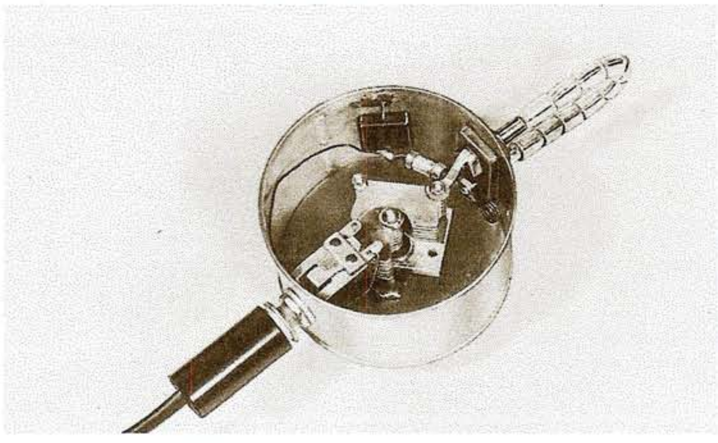
The tune-up procedure is quite simple. The absorption-type wavemeter is tuned to the lowest harmonic causing TVI. It is then brought in close proximity to the tank circuit of the first stage in the equipment and the series-inserted plate trap is tuned to reduce the offending harmonic to a minimum. It will be found that several minimums will be noted as the 3- to 30-μμf trimmer capacitor is adjusted from minimum capacitance to maximum capacitance. In the doubler and final stages, however, care must be taken to avoid tuning to the output frequency so that the 3- to 30-μμf capacitor will not tend to arc over and burn up. After testing over the entire range with the wavemeter, choose the setting at which all harmonics, even and odd, above and including the offending harmonic are reduced to a minimum. The tank-coil trap is then tuned for still further harmonic reduction. The process is repeated for each stage, in order, ending with the antenna-tuning stage. A further check is made at the antenna feeders to make sure that no harmonic emission is detectable. The final, and most important check, of course, should be made on the nearest television receiver.

Field Tests

In several rigorous field tests, this system of reducing TVI gave excellent results. One test was made

(Continued on Page 3, Column 1)

LOOKING INSIDE



An interior view of the wavemeter shows placement of components. The rotor plates of the variable capacitor may be trimmed in order to make the frequency response of the unit more linear at the high-frequency end.

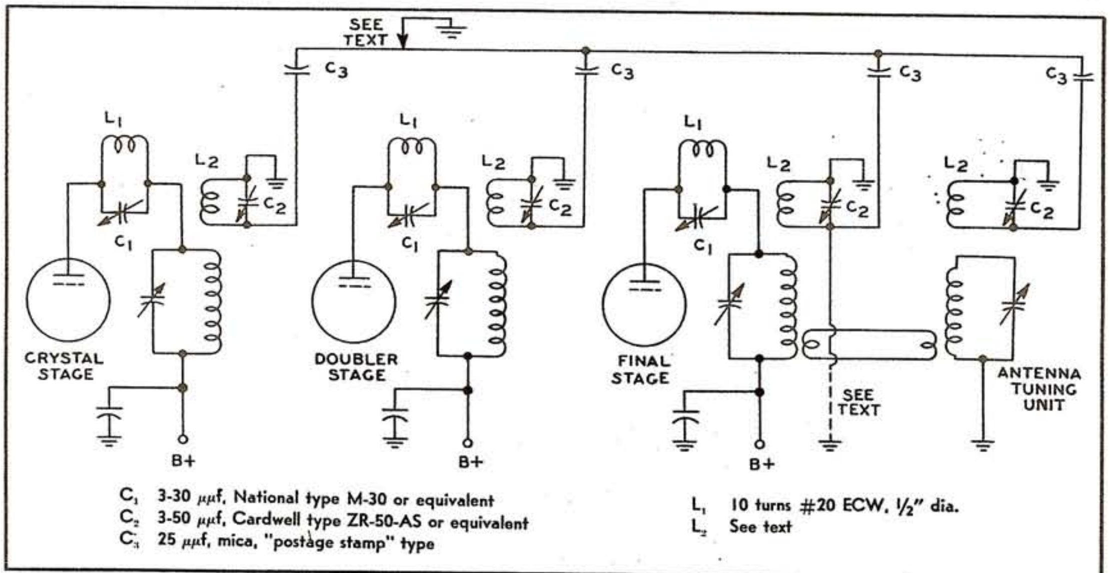


Figure 4. Partial schematic of transmitter showing manner in which harmonic-cancelling traps are placed in circuit.

HARMONIC OUTPUT

(Continued from Page 2, Column 4)

at the writer's home station in Lancaster, Pa. The regular 20-meter folded dipole 45 feet high was located within 50 feet of the television antenna also 45 feet high. The transmitter was operated with 300 watts input and caused no interference on channels 3 and 6 originating in Philadelphia 65 miles away. For these tests the TV screen was viewed at a distance of approximately 40 inches in order to obtain the standard 4-to-1 viewing ratio for a 10-inch kinescope.

For a more strenuous test, the transmitter was then taken to Harrison, N. J., where it was operated in the same room with a commercial television receiver. All 6 channels in the New York area were sampled and were clear of transmitter interference to a degree considered unattainable before the tests began.

In Lancaster, the system was tried and is still in use on a Collins 32V transmitter operating on 10 meters with equally satisfactory results.

Although this system has worked remarkably well in every transmitter the author has modified, it should be recognized that each case of TVI presents special problems and requires experimentation.

(1) *Mack Seybold "Curing Interference to Television Reception," QST, August 1947 Vol. XXXI, No. 8, pp 19-23.*

ECHOES

The High-Fidelity Audio Amplifier described in the September-October 1948 issue of HAM TIPS inadvertently listed C12 as a 0.01 uf capacitor. Actually the capacitance should have been shown as 0.1 uf.

VFO UNIT

(Continued from Page 1, Column 2)

the high rf resistance of the chassis will cause a substantial reduction in "Q".

A large portion of the drift due to temperature changes results from expansion, twisting, and warping of the chassis and panel. The heavier the chassis and panel are, however, and the more substantially they are fastened together, the less the frequency drift will be. To appreciate fully the order of stability required, it should be remembered that a shift of only 500 cycles will be 4000 cycles when multiplying from the 3.5-Mc band to 28 Mc. Also, it is not uncommon for receiver oscillators, particularly of the broadcast variety, to drift as much as several thousand cycles.

Frequency drift due to changes in operating conditions is minimized by using a well-regulated power supply.

Circuit Details

Excellent descriptions of the Clapp oscillator circuit are given in the references and need not be repeated here. The complete circuit of the VFO is given in Figure 5, on Page 4. The frequency-determining circuit consists of L_1, C_7, C_8, and the series-parallel combination of C_1 to C_6, all in series. Because the capacitive reactance of C_1 to C_6 cancels a portion of the inductive reactance of L_1, a relatively large inductance may be used. This large inductance, plus the fact that the 6AG7 grid No. 1 is effectively tapped across only a portion of the tank circuit, provides a circuit with extremely high "Q". When the 6AG7 is connected as an electron-coupled oscillator, it is possible to use a considerably larger coil for L_1 with a further reduction in the effects of voltage and tube changes on frequency stability. However, if such a circuit is used, the actual tuning capacitance becomes smaller and the effects of temperature and mechanical changes in the chassis and tank circuit are much greater.

Switch S_1 is used in one position (A) for the 3.5-Mc band. In the other position (B) the higher-frequency bands are spread out when multiplying in later stages to 7 Mc and higher. C_5 is the main tuning capacitor while C_4 and C_6 are the band-spread padders. Considerably greater band spread could be obtained if the 11-meter band were not included. C_3 is the 3.5 Mc band-set capacitor. C_1 and C_2 compensate to some degree for changes in temperature. The oscillator operates with a screen current of about 1.5 ma at 75 volts and a plate current of only 5 ma at 180 volts. Keying of the cathode circuit causes no perceptible change in frequency, and no chirp nor other transient.

The 6AG7 was selected as a class A buffer because, due to its high transconductance, it is capable of about 3 watts output with negligible grid power or voltage requirements. Across a 10,000-ohm load, about 70 volts are developed at the output connections of this circuit. This voltage is more than sufficient to drive the regular crystal stage of a transmitter.

The buffer amplifier plate and screen currents total about 20 ma with the plate operating at 250 volts. A low-value coupling capacitor (C_{12}) plus the use of dropping resistor R_2 prevents the following stages from affecting the oscillator frequency. In fact, the frequency shift, from full load to no load (complete disconnection of the coaxial output lead) is only one or two cycles. The output circuit, L_2 link-coupled through a coaxial feeder to L_4, is low in capacitance and gives nearly uniform output over the entire 3.5-Mc band when C_{16} and C_{17} are stagger tuned.

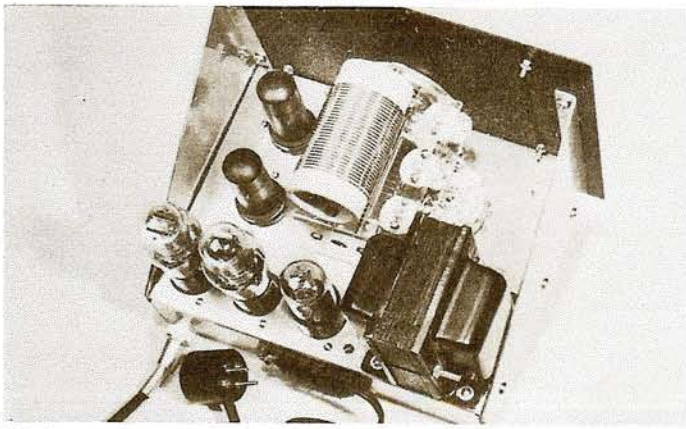
The voltage-regulator tubes largely eliminate the effect of variations in line voltage. A decrease of 20 volts in line voltage causes less than a 10-cycle shift in frequency. The power supply, conventional in design, has a total drain in the order of 50 ma. Because it is often desirable to provide complete control of the rig from the VFO unit, switch S_2 was added to provide switching circuits for the receiver and the power relay of the transmitter final. The standby position of the switch permits checking the oscillator frequency before the final is in operation.

Construction Details

Ample room is provided by a 7" x 9" x 2" chassis, preferably of aluminum, with welded or reinforced corners. If an 8" x 10" panel is used, the VFO will fit several types of small standard cabinets. Home-made side brackets of aluminum rigidly tie the panel and chassis together and, to a large degree, prevent warping and twisting. A National type ACN dial is directly calibrated for each band. A "U"-shaped aluminum bracket supports the main tuning capacitor at the front and rear more rigidly than the brackets

(Continued on Page 4, Column 1)

BEHIND-THE-PANEL VIEW



Well planned design of the VFO provides ample space for mounting components. Band-spread and padder capacitors are fixed to a 4-inch strip of polystyrene shown in center of photograph.

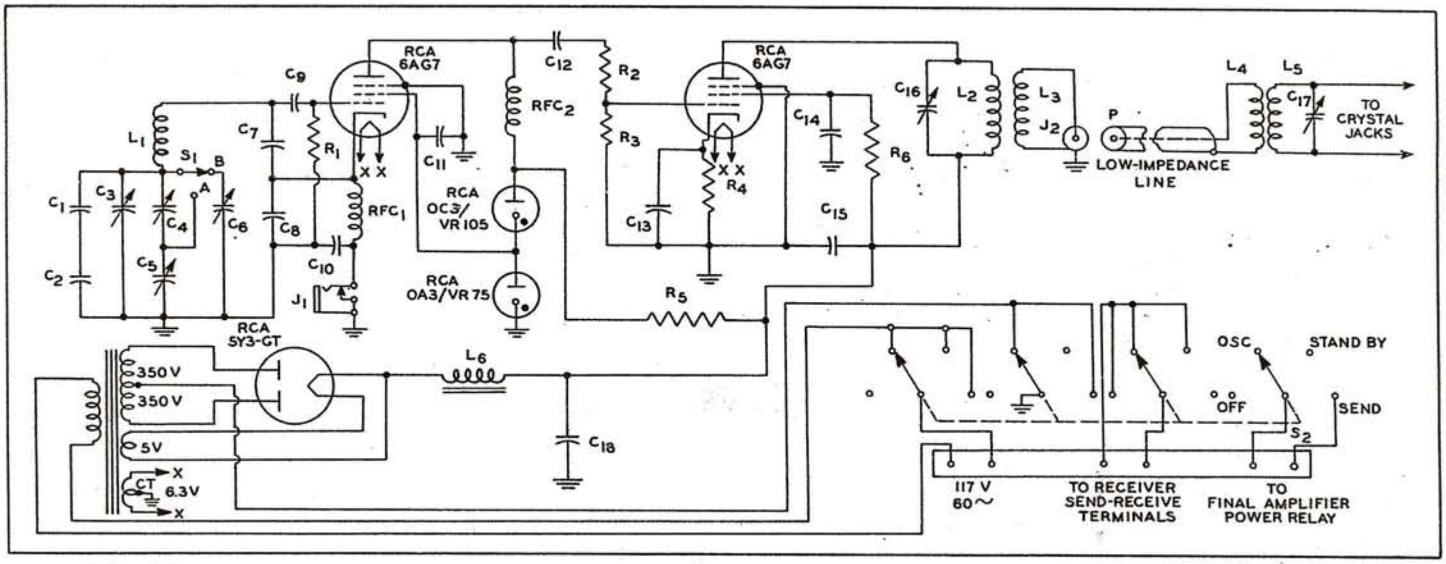


Figure 5. Schematic of variable frequency oscillator.

VFO UNIT

(Continued from Page 3, Column 4)

supplied with the capacitor. In addition, the aluminum bracket provides a support for the coil clear of the chassis and panel thereby reducing the effect of temperature changes. The band-spread and padder capacitors are mounted on a 4-inch strip of polystyrene attached to the side of this bracket. (See photograph on page 3.)

Switch S_1 is mounted face down with the shaft extending through a hole in the top of the chassis. It is controlled from the front panel by means of a flexible shaft. The power supply components are mounted along the rear of the chassis with the filter choke on the underside. The 6AG7 oscillator is directly behind the panel. The two 6AG7 tube sockets are oriented for the shortest possible connections. Except for the usual considerations of providing good mechanical rigidity, short leads, and bringing the rf returns for each stage to a common point, the wiring is simple and not critical. No trouble should be experienced with self oscillation.

L_2 is wound on a medium-sized octal tube base from which the pins have been removed. The tube base is then fastened to the chassis by means of a screw through the bakelite positioning plug. Capacitor C_{16} is mounted inside the coil. A three-turn link (L_3) wound on L_2 at the low-voltage end is connected to receptacle J_2. A suitable length of B & W Miniductor (one-inch diameter and having 32 turns per inch) may be substituted for L_2 if desired. A low-impedance transmission line of any reasonable length connects the output jack to L_5 and L_4. Because high "Q" was not particularly desired for L_4, it was random wound on a form together with L_5, its three-turn link, and inserted in a four-pin tube base with the pin spacing altered to fit the standard crystal pin spacing. If room permits, however, the use of a suitable plug-in type coil form will simplify the construction.

The frequency drift, even without temperature compensation, will not be excessive. Some adjustment of the degree of compensation, however, may be desirable and can be easily accomplished by changing the value of capacitor C_1. Any check of the keying characteristics should include listening on one of the higher-frequency bands because any defects will be considerably accentuated by frequency multiplication.

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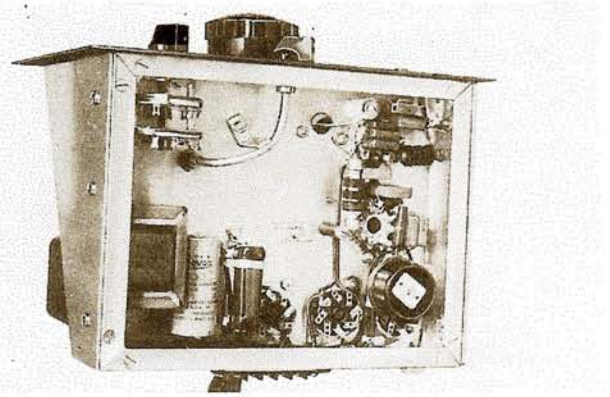
(1) *J. K. Clapp, "An Inductance-Capacity Oscillator of Unusual Frequency Stability," Proc. I. R. E., March 1948. "Technical Topics," May and Oct. 1948 QST. Nicholas Lefor, "The 'Topics' VFO," Aug. 1948 QST.*

PARTS LIST

C1	15 uuf, zero temperature, Centralab style NPO
C2	100 uuf, negative temperature, Centralab style N750
C3	6-75 uuf, Hammarlund type APC-75 or equivalent
C4	7-100 uuf, Hammarlund type APC-100 or equivalent
C5	10-75 uuf, Bud #CE-2014 or equivalent
C6	5-50 uuf, Hammarlund type APC-50 or equivalent
C7, C8	0.001 uf, silver mica
C9	100 uuf, silver mica
C10, C11, C13, C14, C15	0.005 uf, mica
C12	15 uuf, silver mica
C16, C17	3-30 uuf, mica
C18	20 uf, 450 working volts, electrolytic
R1, R3	100,000 ohms, ½ watt
R2	27,000 ohms, ½ watt
R4	100 ohms, ½ watt
R6	15,000 ohms, 1 watt
R5	2,000 ohms, 10 watts
T1	Transformer, 350-0-350 volts at 90 ma., 5 volts at 2 amps, 6.3 v at 3.5 amps. Thordarson No. T17R37 or equivalent
L_1	28 turns, No. 18 enamel, spaced over 2⅜", on 1¾" dia x 3½" National No. XR13 Ceramic coil form or equivalent
L_2	No. 26 enamel close wound $\frac{13}{16}$" on 1$\frac{5}{16}$" dia. form. B & W Miniductor (Cat. 3016) may be substituted
L_3	3-turn link wound on L_2 at low-voltage end.
L_4	56 turns No. 26 enamel, random wound approx. ¾" on 1⅛" dia. form
L_5	3-turn link, wound on L_4
RFC_1, RFC_2	Choke, 2.5 mh, 125 ma
L_6	Choke, 8-24 henry, 80 ma, Thordarson No. T20C53 or equivalent
S_1	Switch, 4-position, 1-section Mallory Hamband switch.
S2	Switch, 2 gang, 4 circuit, 4-point rotary
J_1	Closed circuit jack for key
J_2	Coaxial receptacle
P	Coaxial plug

VFO UNDER-CHASSIS



Aside from the usual considerations of providing mechanical rigidity, short leads, and bringing rf returns for each stage to a common point, the wiring of the VFO is simple and not critical.

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H. S. STAMM, W2WCT .... *Editor*
JOHN L. REINARTZ, W3RB .... *Technical Adviser*

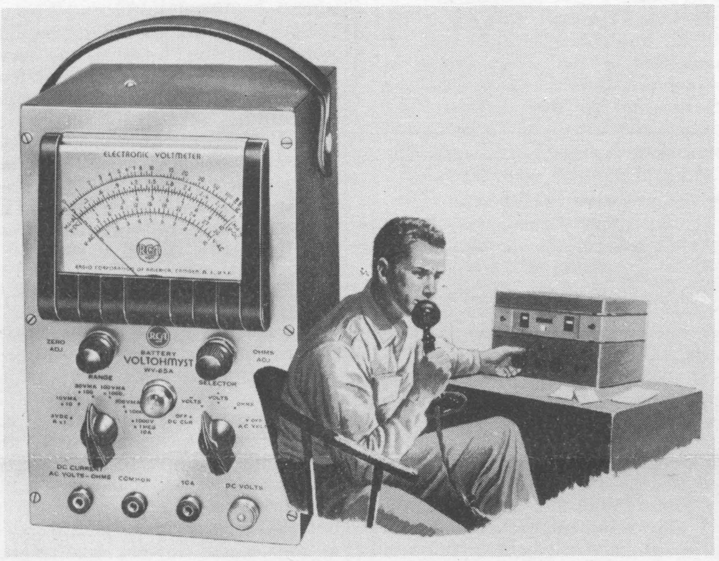
RCA Ham Tips

PUBLISHED - IN - THE - INTEREST - OF - RADIO - AMATEURS - AND - EXPERIMENTERS

VOLUME IX, No. 3 EDITORIAL OFFICES, RCA, HARRISON, N. J. JULY, 1949

A SIMPLIFIED PROCEDURE FOR DESIGNING AUDIO MODULATORS

RCA WV-65A BATTERY VOLTOHMYST*



This popular instrument is particularly suited for a wide number of Amateur circuit applications. It can be used for accurate measurements of ac and dc voltage, for dc current, and for resistance. As a working tool, it belongs in every Ham Shack.

* Reg. Trade Mark, U. S. Pat. Off.

RCA VOLTOHMYST* ELECTRONIC METER IS HIGHLY VERSATILE IN HAM SHACK

By A. M. SEYBOLD, W2RYI
RCA Tube Department

Several million man-hours of work are spent each year by radio amateurs in building and repairing ham rigs. Part of that time is consumed in a sort of happy leisure, with the old soldering iron filling the shack with the pleasant odor of hot rosin flux. Likewise, some of those hours are burned away in the white heat of trying to finish a gimmick for testing a new idea or trying to get the rig back on the air to meet a sked or hit the zero hour for a contest. But, no matter what the project on hand may be, or whether your bench is in the cellar between the laundry tubs and the furnace, or "upstairs" with sound-proofed walls and carpeted floors, work-shop activity is a mighty important part of amateur radio.

Your tools for that work determine how pleasantly the time at the bench can be spent. Actually, minor miracles can be performed with a screw-driver, pliers, a hand drill, a file, and an old soldering iron. If your mechanical equipment fills the bill for the jobs you have on hand, how about the electrical end of the business?

The end product of your efforts is electronic equipment. If you have a tool that can get down into the circuit you're working on and give the right dope on what's going on, you're going to end up with a rig that does what it's supposed to when it's supposed to. If you have one electrical tool that is capable of working in a variety of circuits, that tool belongs in the important category represented by screw-drivers and pliers, and it belongs on your bench in a position just as accessible. I have been using an

(Continued on Page 3, Column 2)

*Reg. Trade Mark, U. S. Pat. Off.

MODULATOR DESIGN MADE FLEXIBLE BY APPLICATION OF BASIC FORMULAS

By A. G. NEKUT, W3LIL
RCA Tube Department

In most amateur applications the problem of choosing a suitable audio modulator circuit is affected at the start by certain fixed conditions in the ham shack. Usually, for example, the modulator plate-supply voltage is fixed by the power supplies available. Often the modulation transformer available has an "impedance" rating that may not fit the value of plate-to-plate load resistance published under the typical operating conditions for the modulator tubes desired. It is the purpose of this article to present simplified design formulas which will aid in the design of a satisfactory modulator stage.

Because efficiency and economy of operation are usually of the utmost importance, this discussion will be limited to push-pull circuits using (1) beam power tubes, (2) power pentodes, or (3) power triodes operating in the positive grid region. Screen-grid type tubes may be operated under either high-bias class AB_1 or class AB_2 conditions; triode types operate, of course, under high-bias class AB_2 or class "B" conditions.

Let us start off with values of dc plate voltage (E_{bs}) and dc plate current (I_{bs}) of the fully loaded class "C" rf stage which is to be plate modulated. These values have been either computed [1] or obtained from published class C telephony operating conditions for the desired tube type.

The average audio power (W_a) in watts required to fully modulate this input power with sine-wave modulation is obtained as follows[2]:

$$\text{Required average audio power } W_a = \frac{\text{dc plate voltage } E_{bs} \times \text{dc plate current } I_{bs}}{1.7} \qquad (1)$$

where E_{bs} is in volts and I_{bs} is in amperes.

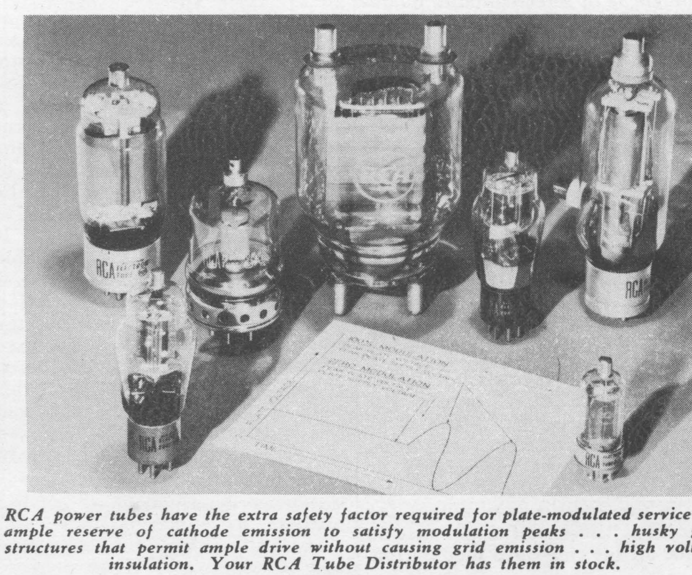
The ac load resistance (R_s) in ohms presented to the modulation transformer secondary by the rf stage is given by

$$\text{AC load resistance } R_s = \frac{0.85\, E_{bs}}{I_{bs}} \qquad (2)$$

Equations (1) and (2) allow for an efficiency factor chargeable to the modulation transformer and arbitrarily set at 85%. No specific allowance has been made for

(Continued on Page 2, Column 1)

IT'S SAFETY FACTOR THAT COUNTS



RCA power tubes have the extra safety factor required for plate-modulated service . . . ample reserve of cathode emission to satisfy modulation peaks . . . husky grid structures that permit ample drive without causing grid emission . . . high voltage insulation. Your RCA Tube Distributor has them in stock.

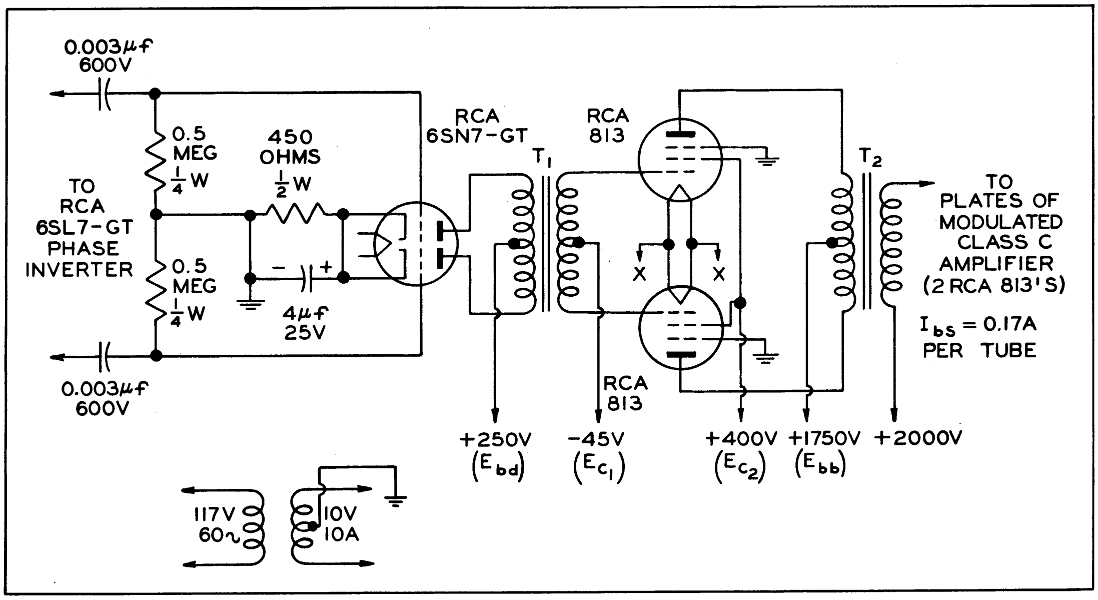


Figure 1. Modulator circuit designed from calculations given in text. It has not been built, and therefore, test data are not available.

Notes:
1) All power supplies returned to ground.
2) E_{c1} to be obtained from a source of good regulation (internal impedance equal to or less than 200 ohms).
3) The 250-volt supply may be obtained from a tap on bleeder for E_{c2} supply. Minimum bleeder current should be approximately 0.05 amperes.
4) T_1 = Driver Transformer—5-watt audio level—Total primary to ½ secondary turns ratio = 3.
5) T_2 = Modulation Transformer—400-watt audio level—one-half primary to total secondary turns ratio = 0.8.
6) E_{c2} and E_{bb} supplies should be adequately bypassed to ground for audio frequencies. Radio-frequency bypass capacitors at tube socket may be required under some conditions.

MODULATOR DESIGN

(Continued from Page 1, Column 4)

screen-modulation power which is usually negligible if a screen-voltage tap is available on the modulation transformer. If a dropping resistor is used to supply the screen with modulated voltage, the screen current per tube of the modulated stage should be added to I_{bs} before W_a and R_s are computed. It should be noted that satisfactory plate modulation of screen-grid tubes often results if the screen is fed from an unmodulated voltage source through an audio choke or a high resistance.

Design Procedure

Let us assume that the dc plate supply voltage for the modulator stage (E_{bb}) is fixed, and the design problem is to select suitable modulator tubes and a modulation transformer to meet the conditions imposed above. The following approximate relations will be used:

For E_{bb} in range from 400 to 750 volts	For E_{bb} in range from 1250 to 3500 volts	
$I_b = \frac{0.75\,W_a}{E_{bb}}$	$I_b = \frac{0.71\,W_a}{E_{bb}}$	(3)
$W_p = 0.25\,W_a$	$W_p = 0.21\,W_a$	(4)
$W_{in} = 0.75\,W_a$	$W_{in} = 0.71\,W_a$	(5)
$R_{pp} = \frac{1.3\,E_{bb}^2}{W_a}$	$R_{pp} = \frac{1.7\,E_{bb}^2}{W_a}$	(6)

$$r = \sqrt{\frac{R_{pp}}{4R_s}} \qquad (7)$$

In the above relations, I_b is the max.-signal dc plate current *per tube* in amperes, W_p is the max.-signal plate dissipation *per tube* in watts, W_{in} is the max.-signal dc power input per tube in watts, and W_a is the audio power output for *two tubes* (push-pull stage) also in watts, all for sine-wave modulation. R_{pp} is the plate-to-plate load resistance presented to the modulator tubes, and r is the turns ratio of the modulation transformer defined as

$$\text{Modulation transformer turns ratio } r = \frac{\text{½ total number of primary turns}}{\text{number of secondary turns}} \qquad (8)$$

It is assumed, of course, that the primary of the modulation transformer is center tapped and that the secondary feeds the class "C" rf stage to be plate modulated.

Modulator Tube Selection

Suitable modulator tubes (either screen-grid or triode types) may now be selected on the basis of maximum ratings[3] for either class AB_2 or class B audio service (or class C telegraphy ratings if audio ratings are not given) that are equal to or in excess of the values found from equations (3) to (6). It is evident from inspection of equations (6) and (7) that the selection of E_{bb}, R_s, and W_a automatically fixes the modulation transformer turns ratio, r. If a transformer having a different turns ratio is already available in the ham shack it will be necessary to change either one or all of the three quantities listed in order to make use of this transformer. If the turns ratio of the available modulation transformer is lower than the value given by equation (7), it is possible to operate the modulator tubes into a lower than optimum value of R_{pp}. However, unless E_{bb} is lowered also, this mode of operation is very inefficient and equations (3), (4), (5), and (6) are no longer valid. It should be noted that

$$\text{Modulation transformer turns ratio } r = \sqrt{\frac{Z_p}{4Z_s}} \qquad (7a)$$

where Z_p is the rated "impedance" of the total primary winding and Z_s is the rated "impedance" of the secondary winding.

After a suitable tube type has been selected, the published "Average Plate Characteristics" curves ("plate family") for this type should be used to determine suitable operating values. For screen-grid tubes a value of screen-grid voltage—and suppressor-grid voltage, if required—which can be readily obtained in the ham shack from a power source having good voltage regulation must be selected. A straight (load) line is drawn on the "plate family" curves connecting the point determined by "Plate Amperes" = 0 and "Plate Volts" = E_{bb} to the point determined by "Plate Volts" = 0 and "Plate Amperes" = I'_b where

$$I'_b = \frac{4E_{bb}}{R_{pp}} \qquad (9)$$

The optimum value of grid-No. 1 bias may now be obtained from the relation

$$\text{Optimum grid bias } E_{c1} = -\frac{(e_1 i_2 - e_2 i_1)}{(i_1 - i_2)}, \qquad (10)$$

where the values of e_1 and e_2 are convenient intermediate values of grid-No. 1 voltage taken from the intersection of the load line with the bias curves, and i_1 and i_2 are the corresponding plate currents. In this equation it is assumed that the "e" and "i" points chosen lie on a linear portion of the tube's dynamic transfer characteristic and that the plate current of the non-working tube of the push-pull connection is zero. For this reason, the values of "e" and "i" chosen for equation (10) should lie well up on the load line but should not include points near the "knee" of the curve where some non-linearity may usually be expected. The plate dissipation under zero-signal conditions (W_{po}) may now be checked. Proceeding vertically upwards from E_{bb} on the "plate family" curves, read the value of plate current I_{bo} at the value of E_{c1} computed from equation (10). Then,

$$\text{Zero-signal plate dissipation } W_{po} = E_{bb} I_{bo} \qquad (11)$$

This value of W_{po} (zero-signal plate dissipation per tube) should not exceed approximately 1/3 to 1/2 of the maximum rated plate dissipation of the tube. If the value of E_{c1} found from equation (10) is not sufficiently negative to limit W_{po} to the desired value, it may be made more negative at the expense of only a slight increase in distortion at max.-signal levels; small-signal operation will produce larger amounts of distortion, but this mode of operation is generally of no consequence in modulator designs for voice communication. The peak af grid-No. 1-to-grid-No. 1 voltage (E_{gg}) in volts may be obtained from

$$\text{Peak af grid-No. 1-to-grid-No. 1 voltage } E_{gg} = 2\,(e_{gm} - E_{c1}) \qquad (12)$$

where e_{gm} is the instantaneous grid voltage obtained from the "plate family" curves at the intersection of the load line with the knee of the curve. If the tube chosen is a filamentary type and if the "Aver-

(Continued on Page 3, Column 1)

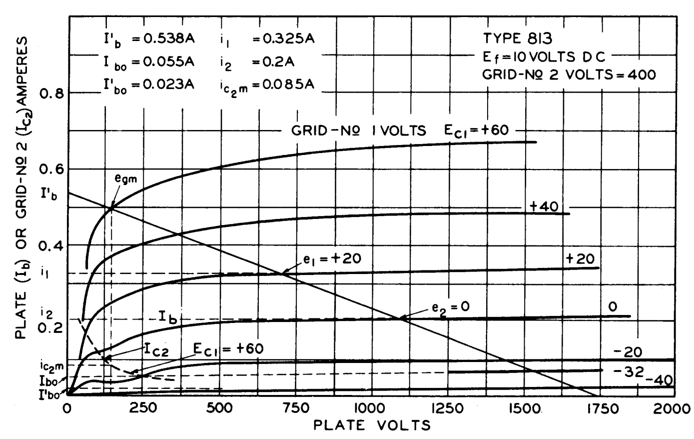


Figure 2. Average plate characteristics of the RCA-813.

MODULATOR DESIGN

(Continued from Page 2, Column 4)

age Plate Characteristics" curve is shown for a dc filament voltage (E_f), the grid bias value E_{c1} found from equation (10) should be made

more negative by $\frac{E_f}{2}$ volts when the

tube is used with an ac filament-voltage supply. This new value for E_{c1} should not be used in any of the calculations, however.

Driver Stage

A suitable driver stage and the turns ratio of the driver transformer may now be determined from the following considerations. If no current is drawn by grid No. 1 of the modulator tube, any conventional resistance-capacitance-coupled push-pull or phase-inverter voltage amplifier, comprising either triodes or pentodes, capable of supplying the required value of peak af grid-No. 1-to-grid-No. 1 voltage E_{gg} to the modulator circuit may be used.[4] If current is drawn by grid-No. 1 of the modulator tube, the following approximate relations are useful. For conventional low- and medium-mu triodes for the driver stage in push-pull class A or AB_1 connection

The driver transformer turns ratio r_d =

$$\frac{2.4E_{bd}}{E_{gg}} \qquad (13)$$

and

Driver tube max. allowable plate resistance

$$R_{pm} = \frac{r_d E_{bd}}{6.7 i_{gm}} \qquad (14)$$

where r_d is the driver transformer turns ratio and is defined as

$$r_d = \frac{\text{total number of primary turns}}{\frac{1}{2}\text{ number of secondary turns}} \qquad (15)$$

E_{bd} is the plate supply voltage of the driver stage, i_{gm} is the instantaneous grid current drawn by grid No. 1 of the modulator tube in amperes at the value of e_{gm} used in equation (12), and R_{pm} is the maximum allowable driver-tube plate resistance in ohms. Tubes with values of R_p higher than indicated by equation (14) may be used but somewhat higher distortion will result. For single-ended class A driver circuits using conventional low- and medium-mu triodes

$$r_d = \frac{1.2\, E_{bd}}{E_{gg}} \qquad (16)$$

Equations (14) and (15) also apply in this case. The power rating of the driver transformer should be adequate to handle at least the rated power output of the driver tube(s) in conventional class "A" (or AB_1 as the case may be), audio power-amplifier service.

The final value to be determined in computing tube operation is the screen-grid dissipation. Useful relations for approximating the value of average screen current (I_{c2}) in amperes and screen dissipation (W_{c2}) in watts at max.-signal levels are

Average screen current $I_{c2} = \frac{i_{c2m}}{4}$ (17)

Screen dissipation

$$W_{c2} = I_{c2}\, E_{c2} \qquad (18)$$

where i_{c2m} is the instantaneous value of screen current in amperes flowing when the instantaneous grid-No. 1 voltage is equal to e_{gm}, and E_{c2} is the dc screen voltage.

Modulation Transformer

Before proceeding with an example to illustrate the use of the relations given above, a brief discussion of modulation transformer "impedance" ratings may prove useful. Modulation transformers are usually rated in terms of primary

(Continued on Page 4, Column 1)

BATTERY VOLTOHMYST

(Continued from Page 1, Column 2)

RCA WV-65A Battery VoltOhmyst for that kind of work, and I'd like to nominate it for a permanent position in the screw-driver league. Let's have a look at some of the things this compact little battery-operated VoltOhmyst does for me.

DC Voltage Measurements

For measuring dc voltages, it's wonderful. The input resistance for all dc voltage scales (0-3 through 0-1000) is 11 megohms. This high value makes it possible to take voltage readings on even high-resistance circuits like avc lines and the control-grid circuits of a resistance-coupled audio amplifier. The insulated probe used for dc voltage measurements is shielded and contains a one-megohm isolating resistor which permits reading dc voltages at points such as the grid of a grid-leak self-biased oscillator where there is appreciable rf. The case of the meter is a good rf shield, so if the ground return is made to the outside of the box rather than through the pin jack normally used, dc voltage readings can be taken right next to a high-power plate tank with no error introduced by the rf field. Whenever it is necessary to make dc voltage measurements in the presence of heavy rf voltages, I pull out the "common" jack connector, and connect the ground return wire to the outside of the instrument case. I've used the Battery VoltOhmyst on my transmitters for 3.5, 14, 28, and 144 Mc, and have had no evidence of rf getting into the case at any of those frequencies.

By the way, the accessory RCA High-Voltage probe, WG-284, permits one to read up to 3000 volts dc full scale on the 30-volt position, 10,000 volts on the 100-volt position, and 30,000 volts on the 300-volt position. This probe gives an extremely high-resistance method of examining high dc voltages, and has come in mighty handy for work on my 14,000-volt kick-back television supply.

Some other places where this instrument has come in handy for reading voltages are as follows: bleeders and voltage dividers, grid-leaks, screen-dropping circuits, tube sockets, bias lines, and voltage regulator tube circuits.

DC Measurements

The dc current range of the Battery VoltOhmyst will handle most of the jobs a ham encounters. All scales, from the 0-3 milliampere to the 0-10 ampere settings, operate directly through the meter and do not require battery current. In the dc current-measuring position, the VoltOhmyst case is electrically isolated from the test leads. This feature permits current measurements to be made in high-voltage circuits without danger of shock from the meter case. For extra safety, the case can be grounded.

AC Voltage Measurements

The ac voltage scales on the Battery VoltOhmyst are also operated without the use of the internal battery supply. For these measurements also, the case is isolated electrically from the test leads. The sensitivity of the meter is 1000 ohms per volt. Measurements of power-transformer voltages, filament supplies, low-impedance audio circuits, and low-frequency rf potentials can readily be made.

For rf-voltage measurements and for low-frequency readings in high-impedance circuits, accessory RCA Crystal Probe, WG-263 is available. The probe connector goes right on the dc fitting, and the dc scales are used; they give readings of some values in the convenient RMS volts. The ac voltage sensitivity of the Battery VoltOhmyst is increased markedly by the use of this accessory, which makes it possible to do such things as track audio signals through resistance-coupled amplifiers and follow rf signals through the multiplier stages of transmitters.

Resistance Measurements

Because of the amplification obtained with the vacuum tube bridge circuit when the ohm scales are used, a wide range of resistance readings, from 0.1 ohm to 1000 megohms, is available. Consequently, the VoltOhmyst is an extremely versatile tool for checking resistor values when equipment is being built or repaired. Leakage paths in wiring can be checked, and leakage in transformers, sockets, capacitors, and other components can be found readily. If leakage paths or resistances above 1000 megohms are to be studied, use of the voltage probe and an external dc supply makes it possible to measure resistances in the order of tens-of-thousands of megohms.

Just recently my 10-meter transmitter went off the air during a QSO. The HV plate-supply fuse blew. I checked the plate line with the VoltOhmyst expecting to find a dead short, but the only evidence of a defect I could find was 50 megohms of leakage. I tracked this leakage with the meter to a lead-through bushing. There a fire-charred path had formed in the insulation. Of course I replaced the bushing and got the rig back on the air, but later I checked the defective part to see what had happened. Up to 400 volts, that leakage path stayed 50 megohms, but above 400 the charred path would arc through and produce a dead short. The VoltOhmyst had done a quick, sweet job in locating that screwball defect which would not have produced even the slightest deflection on an ordinary non-electronic volt-ohm-multiammeter.

Portability

Another good feature of the Battery VoltOhmyst is its portability. When you move the instrument around on the bench, or place it in a convenient spot at the transmitter or receiver, you don't have to juggle a power line or look for an extension cord, or reposition the meter to make measurements. The device is all set to go wherever it is put in either a vertical or horizontal position. For the boys with the mobile rigs and the field-day set-ups, the Battery VoltOhmyst comes right off the bench in the shack into the great outdoors and packs along as a sensitive, accurate, compact servicing tool that can be counted on in any emergency.

Specifications of the WV-65A Battery VoltOhmyst

DC Voltmeter:	
Six Ranges	0-3, 0-10, 0-30, 0-100, 0-300, 0-1000 volts
Input Resistance	11 megohms constant for all ranges
Sensitivity (max.)	3.7 megohms per volt on 3-volt range
AC Voltmeter:	
Five Ranges	0-10, 0-30, 0-100, 0-300, 0-1000 volts
Sensitivity	1000 ohms per volt
Ohmmeter:	
Six Ranges	0-1000, 0-10,000, 0-100,000 ohms, 0-1, 0-10, 0-1000 megohms
DC Ammeter:	
Six Ranges	0-3, 0-10, 0-30, 0-100, 0-300 milliamp. and 0-10 amp.
Voltage Drop	450 mv. for full scale deflection
Power Supply:	
Batteries	Four 1½ volt RCA-VS036 Two 45 volt RCA-VS055
Tube Complement	2 RCA-1C5GT, 1 GE-NE51
Finish:	
Panel	Etched brush chrome
Case	Gray wrinkle
Dimensions	9½" high, 6¼" wide, 5½" deep
Weight	9 lbs. (incl. batteries)

MODULATOR DESIGN

(Continued from Page 3, Column 2)

and secondary "impedance" and audio power (or more properly KVA) capability. The peak ac voltage (E_{pm}) that may be applied to ½ of the modulation transformer primary is

$$\text{Peak ac voltage across primary } E_{pm} = \sqrt{\frac{W_t Z_{pm}}{2}} \qquad (19)$$

where Z_{pm} is the maximum impedance rating of the entire primary in ohms and W_t is the rated audio-power-handling capability of the transformer in watts. Similarly, the peak ac voltage (E_{sm}) permissible across the transformer secondary winding (equal to the dc plate voltage of the plate-modulated rf amplifier for 100% modulation) may be found from

$$\text{Peak ac voltage across secondary } E_{sm} = \sqrt{2\, W_t Z_{sm}} \qquad (20)$$

where Z_{sm} is the maximum secondary-impedance rating of the transformer. Of course, any voltage (and impedance) lower than these maximum rated values may be used. However, in order not to exceed the ac current ratings implied in the audio power and impedance ratings of a transformer having a fixed turns ratio, the power-handling capability of a transformer should be reduced approximately in accordance with the relation

$$W'_t = \frac{W_t R_s}{Z_{sm}} \qquad (21)$$

where R_s (as defined previously for equation (2)) is *less* than Z_{sm} and W'_t is the reduced audio-power-handling capability of the transformer. The dc current ratings of both primary and secondary windings are assumed to remain constant when the transformer is operated at other than rated impedance levels, although a reduction in primary dc current may allow some increase in ac current (allowing W'_t as given in equation (21) to be increased somewhat) and a reduction in secondary dc current may allow a slight increase in both E_{sm} (as given in equation (20)) and W'_t. For modulation transformers of the "multimatch" type it is assumed (unless information to the contrary is published by the manufacturer) that full power-handling capability has been preserved by proper design for all rated impedance values.

Example

As an example, let us assume that the class "C" rf amplifier to be modulated is a push-pull circuit using 2 RCA-813's with a dc plate voltage (E_{bs}) of 2000 volts and a dc plate current (I_{bs}) of 0.17 amperes for each tube or 0.34 amperes for both. From equation (1), we obtain

$$\text{Required average audio power } W_a = \frac{E_{bs} I_{bs}}{1.7} = \frac{(2000)\ 0.34}{1.7} = 400 \text{ watts}$$

From equation (2), we obtain

$$\text{AC load resistance } R_s = \frac{0.85\, E_{bs}}{I_{bs}} = \frac{0.85\ (2000)}{0.340} = 5000 \text{ ohms}$$

If we assume that it is desired to operate the modulator from a 1750-volt supply, equations (3) to (5) yield

$$\text{Max.-signal dc plate current per tube } I_b = \frac{0.71\, W_a}{E_{bb}} = \frac{0.71\ (400)}{1750} = 0.162 \text{ amperes}$$

$$\text{Max.-signal plate dissipation per tube } W_p = 0.21\, W_a = 0.21\ (400) = 82 \text{ watts}$$

$$\text{Max.-signal dc power input per tube } W_{in} = 0.71\, W_a = 0.71\ (400) = 284 \text{ watts}$$

Inspection of the maximum ratings in the technical data[5] for power tubes shows that either the RCA-813 or the RCA-810 types will easily fulfill all requirements. If a 400-volt screen supply having good regulation is available, the 813 may be chosen to advantage, because this choice will ease the driver stage requirements somewhat in comparison to those required for the RCA-810. Equations (6) and (7) give us the required modulation-transformer impedance and turns ratio ratings.

$$\text{Plate-to-plate load resistance } R_{pp} = \frac{1.7\, E_{bb}^2}{W_a} = \frac{1.7\ (1750)^2}{400} = 13{,}000 \text{ ohms}$$

$$\text{Turns ratio of modulation transformer } r = \sqrt{\frac{R_{pp}}{4R_s}} = \sqrt{\frac{13{,}000}{4\ (5000)}} = 0.806$$

The load line can now be drawn on the curve of "Average Plate Characteristics" shown in Fig. 2 after I'_b is obtained by means of equation (9) as follows

$$I'_b = \frac{4E_{bb}}{R_{pp}} = \frac{4\ (1750)}{13{,}000} = 0.538 \text{ amperes}$$

From equation (10) after points e_1 and e_2 have been selected, we obtained

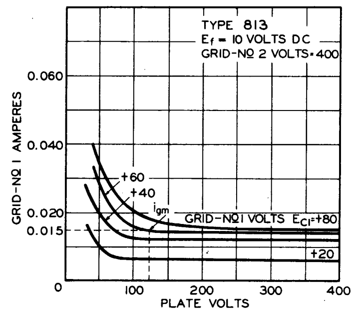


Figure 3. Grid characteristics of the RCA-813.

$$\text{Optimum grid bias } E_{c1} = -\left(\frac{e_1 i_2 - e_2 i_1}{i_1 - i_2}\right)$$

$$= -\left(\frac{20\ (0.2) - 0\ (0.325)}{0.325 - 0.2}\right) = -\frac{4}{0.125} = -32 \text{ volts}$$

The value of I_{bo} at a grid bias of -32 volts is obtained from the family of average plate characteristics and then, from equation (11), we determine

$$\text{Zero-signal plate dissipation } W_{po} = E_{bb} I_{bo} = (1750)\ (0.055) = 96 \text{ watts}$$

Because this dissipation value is in excess of ½ the maximum plate-dissipation rating; that is, greater than $\frac{125}{2}$ or 63 watts, a higher grid bias must be chosen. If a grid bias of -40 volts is used, the zero-signal plate dissipation is

$$W_{po} = E_{bb} I_{bo} = (1750)\ (0.023) = 40 \text{ watts}$$

which is a satisfactory value.

From equation (12), we can determine

$$\text{Peak af grid-No. 1-to-grid-No. 1 voltage } E_{gg} = 2\,[e_{gm} - E_{c1}] = 2\,[60 - (-40)] = 200 \text{ volts}$$

For ac filament operation, an actual bias of -45 volts is required because the average plate characteristics were taken with a dc filament power supply of 10 volts.

If we assume that a push-pull driver stage having a plate supply voltage (E_{bd}) of 250 volts would be most desirable, then from equation (13) we obtain

$$\text{Driver transformer turns ratio } r_d = \frac{2.4\, E_{bd}}{E_{gg}} = \frac{2.4\ (250)}{200} = 3$$

From Fig. 3, at the value of instantaneous grid-No. 1 voltage obtained from the plate family curves at the intersection of the load line with the knee of the curve, e_{gm} = 60 volts. At a plate voltage corresponding to the intersection of the load line and the curve of e_{gm} = 60, the value of instantaneous grid-No. 1 current (i_{gm}) is 0.015 amperes.

Hence, from equation (14) the maximum allowable plate resistance of the driver tube (R_{pm}) is given by

$$R_{pm} = \frac{r_d\, E_{bd}}{6.7\, i_{gm}} = \frac{3\ (250)}{6.7\ (0.015)} = 7460 \text{ ohms}$$

An RCA 6SN7-GT in push-pull class "A" connection will meet the requirements for a driver tube. From Fig. 2 the instantaneous screen current (i_{c2m}) is found to be 0.085 amperes.

From equations (17) and (18), we obtain

$$\text{Average screen current } I_{c2} = \frac{i_{c2m}}{4} = \frac{0.085}{4} = 0.021 \text{ amperes}$$

$$\text{Screen dissipation } W_{c2} = E_{c2} I_{c2} = 400\ (0.021) = 8.5 \text{ watts}$$

This value is well within the ratings for screen power input for the RCA 813. All the pertinent design information for the modulator is given in Table I. Fig. 1. is a typical circuit based on these values.

TABLE I

AUDIO MODULATOR USING 2 RCA-813's IN CLASS AB_2

Values are for 2 tubes

DC Plate Voltage	1750 volts
DC Grid- No. 3 Voltage	0 volts
DC Grid- No. 2 Voltage	400 volts
DC Grid- No. 1 Voltage*	−45 volts
Peak AF Grid- No. 1 to Grid- No. 1 Voltage	200 volts
Zero-Signal DC Plate Current	0.046 amperes
Max.-Signal DC Plate Current	0.324 amperes
Max.-Signal DC Screen Current	0.042 amperes
Effective Load Resistance (Plate-to-plate)	13,000 ohms
Max.-Signal Power Output	400 watts
Output Transformer Turns Ratio, r	0.806
Driver Transformer Turns Ratio, r_d	3
Driver Tube	6SN7-GT (or equivalent)

* For AC filament operation

HAM TIPS is published by the RCA Tube Department, Harrison, N. J., and is made available to Amateurs and Radio Experimenters through RCA tube and parts distributors.

H. S. STAMM, W2WCT .... *Editor*

FOOTNOTES

1. "Simplifying the Calculation of Transmitting Triode Performance" by E. E. Spitzer, "Ham Tips". Nov.-Dec. 1948.
2. Although it is true that considerably less average audio power than the value of Wa given above is required for voice modulation, the peak power capability of the modulator must be adequate if severe distortion at the voice peaks is to be avoided. It is necessary, therefore, to compute the modulator circuit constants for sine-wave signal conditions. Somewhat lower values of plate dissipation than those calculated later will result if voice modulation is used exclusively and this fact may therefore be considered in selecting suitable modulator tubes on the basis of their maximum plate dissipation rating (and, incidentally, in choosing the dc current rating of the modulator plate supply). It is well to remember, however, that if the modulator tubes are chosen with a plate dissipation rating that is only "just sufficient" for voice modulation, a sustained whistle into the "mike" or several seconds of rf, audio circuit, or acoustical feedback, will produce excessive plate dissipation and may result in tube failure.
3. See footnote 2.
4. See pages 196ff in RCA Receiving Tube Manual, RC-15.
5. RCA Tube Handbook HB-3; Headliners for Hams, HAM-103.

RCA Ham Tips

PUBLISHED - IN - THE - INTEREST - OF - RADIO - AMATEURS - AND - EXPERIMENTERS

VOLUME IX, No. 4 EDITORIAL OFFICES, RCA, HARRISON, N. J. SEPT.-OCT., 1949

RCA ANNOUNCES NEW 811-A TRIODE AND HAM RATINGS

Here's tube value that gives you more than your money's worth. Power and performance — huskier construction, greater high-voltage insulation, and a plate structure with radiating fins are just a few of the features that make the new RCA 811-A one of the sweetest power triodes your money can buy. Intended for use as a class B af power amplifier and modulator, it is also well suited for class C telephony and telegraphy. In class B af service and in unmodulated class C service, the 811-A has a maximum plate dissipation of 65 watts (ICAS).

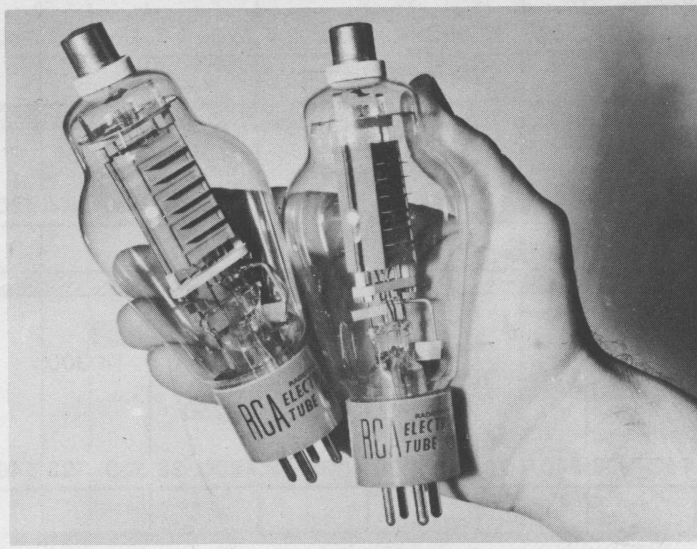
Because of its high perveance, the 811-A operates at high efficiency and with low driving power. For example, a pair of 811-A's in class B af service with a plate input of 470 watts (ICAS) requires a driving power at the tube of only 4.4 watts, and can modulate 100 per cent an rf amplifier having an input of 680 watts.

The RCA 811-A supersedes the 811 and can be used in the same socket without circuit changes. Economy is the keyword in initial cost and operation—Price to amateurs — only $4.05. It's available from local RCA Distributors.

IN YOUR NEXT ISSUE OF RCA HAM TIPS

Don't miss the next issue of RCA HAM TIPS due at your local RCA Distributor November First. In it you'll find a trim little mate for the "Tiny Tran" Mobile Transmitter in the form of a double-conversion, 8-tube, superhet receiver, completely self-contained except for the power supply and speaker. Built in the same small case as the "Tiny Tran", this compact receiver is sure to please the most exacting Ham. It operates on 10 and 11 meters. You'll want to build one like it for your car or shack. Ask your RCA Distributor to reserve your copy of RCA HAM TIPS for you —so you'll be sure to get all the important details.

A SOLID HANDFUL OF POWER



A pair of the new RCA 811-A's in AF or RF, AM or FM, can really deliver the goods. Priced at only $4.05 each, a pair offer you economy and dependability plus.

USING THE RCA-5763 FOR FREQUENCY MULTIPLICATION

By ROBERT M. COHEN, W2LHP
Application Engineer, RCA Tube Department

Amateurs will find many uses for the new miniature transmitting tube, RCA-5763, which operates very efficiently as a doubler, tripler, or quadrupler at frequencies up to 175 Mc. Although intended primarily for mobile service*, its outstanding performance makes it deserving of a place in fixed station equipment where flexible all-band operation is desired.

The basic principles of multiplier operation have been discussed in some detail in previous issues of HAM TIPS**, to say nothing of the reams of technical literature available in the handbooks and elsewhere, so it appears logical to limit our discussion to the particular operating conditions and circuits specifically applicable to the 5763.

Fig. 1A shows the application of the 5763 as a frequency multiplier in the conventional manner. The accompanying photograph (Fig. 1B) shows the lead arrangement and location of parts and is indicative of the generally accepted methods for obtaining short leads and proper circuit bypassing—features necessary for good high-frequency performance.

* "TINY TRAN"–HAM TIPS, May-June, 1949
** "Understanding Frequency Doublers"—HAM TIPS, Jan.-Apr., 1947

Fig. 2 is a family of curves of useful power output versus operating frequency made with this circuit. The term "Useful Power Output" refers to the power which is delivered to the grid of the following tube or the transmission line; it is equal to the total tube power output less circuit and radiation losses. These data, presented in terms of useful power output, are of considerable value to the designer of a transmitter but are not necessarily indicative of tube efficiency, especially at high frequencies where the radiated energy and circuit losses consume a substantial part of the tube output. By way of illustration, the tank circuit power loss including tank circuit radiation is calculated approximately from the unloaded tank-circuit

(Continued on Page 4, Column 1)

FREQUENCY CHART AIDS IN COMPUTING HARMONIC RELATIONS

By 'PAT' PATTERSON, W2VBL
RCA Tube Department

How many times have you rummaged through debris on the operating table looking for a pencil to compute the frequency of a crystal or VFO dial?

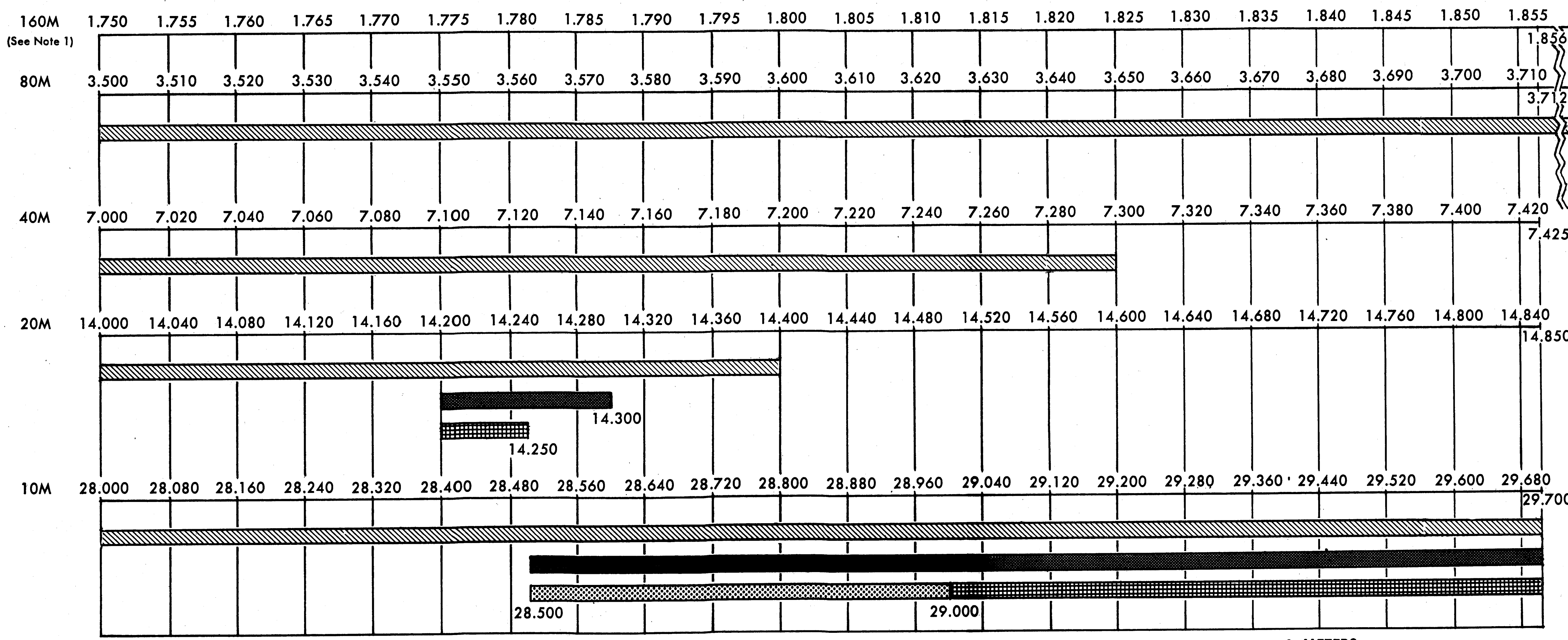
To eliminate the guesswork, we've prepared the handy chart shown on page 2 and 3 of this issue of HAM TIPS. All frequencies are shown in megacycles and have been carried to three decimal places. In many instances, three-place computations do not come out even, hence these figures read low by the quantity of the decimal fraction beyond the third place. Where the figures for the low end of the band do not come out even, the frequencies shown have been extended to the high side of the incomplete decimal fraction in order to show a frequency that is inside the band.

Using the table is a simple matter. For example, a crystal reads 3.645 Mc. After locating this value in the 80 meter column and following it down to 10 meters, it's easy to see the resultant multiplied frequency is 29.160 Mc. Working in the opposite direction: to hit 28.680 Mc, follow the line up to the frequency range of the VFO or crystal, and it shows a setting of 3.585 Mc in the 80 meter band.

The 2, 6, and 11 meter bands do not directly relate to the lower bands, and, therefore, are shown in separate charts. The figures there show the same information, but are computed to several usable submultiples. In two meters, for example, if you are using an 8.055 Mc crystal, you must multiply 18 times to reach the band at 145.00 Mc. (Don't forget — the multiplication factors are not added, but multiplied. X 18 may be reached by tripling, tripling, and doubling, (3 x 3 x 2)). Conversely, to hit 146.5 Mc by multiplying 20 times, a crystal halfway between 7.3 and 7.35, or 7.325, is required.

You'll find good use for this chart. Tack it up on the shack wall near the rig and it will pay for its space in pencils and tempers saved.

FREQUENCY MULTIPLICATION AND DIVISION CHART



KEY

A1 NBFM

A3 FM

TYPES OF EMISSION

A0 ——— Unmodulated Carrier
A1 ——— CW
A2 ——— Modulated CW
A3 ——— Amplitude Mod.
A4 ——— Facsimile
A5 ——— Television
NBFM
FM or Carrier Shift Telegraphy

NOTE 1: Due to the variable status of the 160 meter band at this time, no effort has been made to define its limits. Consult the FCC regulations governing the local area before operating in this range.

2 METERS

÷	144.000	145.000	146.000	147.000	148.000
2	72.000	72.500	73.000	73.500	74.000
3	48.000	48.333	48.666	49.000	49.333
4	36.000	36.250	36.500	36.750	37.000
5	28.800	29.000	29.200	29.400	29.600
6	24.000	24.166	24.333	24.500	24.666
8	18.000	18.125	18.250	18.375	18.500
9	16.000	16.111	16.222	16.333	16.444
10	14.400	14.500	14.600	14.700	14.800
12	12.000	12.083	12.166	12.250	12.333
15	9.600	9.666	9.733	9.800	9.866
16	9.000	9.062	9.125	9.187	9.250
18	8.000	8.055	8.111	8.166	8.222
20	7.200	7.250	7.300	7.350	7.400

6 METERS

÷	50.000	50.500	51.000	51.500	52.000	52.500	53.000	53.500	54.000
2	25.000	25.250	25.500	25.750	26.000	26.250	26.500	26.750	27.000
3	16.667	16.833	17.000	17.166	17.333	17.500	17.666	17.833	18.000
4	12.500	12.625	12.750	12.875	13.000	13.125	13.250	13.375	13.500
5	10.000	10.100	10.200	10.300	10.400	10.500	10.600	10.700	10.800
6	8.334	8.416	8.500	8.583	8.666	8.750	8.833	8.916	9.000
8	6.250	6.312	6.375	6.437	6.500	6.562	6.625	6.687	6.750
9	5.556	5.611	5.666	5.722	5.777	5.833	5.888	5.944	6.000

11 METERS

÷	26.960	27.000	27.040	27.080	27.120	27.160	27.200	27.230
2	13.480	13.500	13.520	13.540	13.560	13.580	13.600	13.615
3	8.987	9.000	9.013	9.026	9.040	9.053	9.066	9.076
4	6.740	6.750	6.760	6.770	6.780	6.790	6.800	6.807
6	4.494	4.500	4.506	4.513	4.520	4.526	4.533	4.538

FREQUENCY MULTIPLICATION

(Continued from Page 1)

parameters by means of the following relation:

$$\text{Total Tank Circuit Loss} = \frac{E^2 2\pi fC}{Q}$$

f = frequency in megacycles
Q = Q of unloaded tank circuit with tube out and circuit restored to resonance
E = RMS value of tank circuit voltage in volts with tank circuit unloaded
C = Total value of tank circuit capacitance including tube, wiring, etc. in microfarads

For the doubler circuit given in Fig. 1 when used in a typical compact mobile transmitter, the total tank circuit loss at 150 Mc is:

$$\frac{(150)^2 \times 6.28 \times 150 \times 15 \times 10^{-6}}{110} = 2.86 \text{ watts}$$

This value, approximately equal to the useful power output, is large but is typical of the normal condition in the 150-Mc region when "lumped circuits" are employed. The tank circuit Q of 110 is reasonably good and the total capacitance of 15 uuf is difficult to reduce.

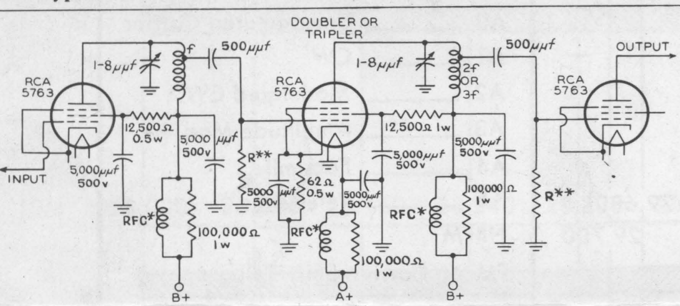
Fig. 3 is a chart giving the recommended operating conditions for the multiplier circuit. Both doubler and tripler operating conditions are given, since the same circuit is used with a change in grid-No. 1 resistance. It is well to remember that when the tube is operated at lower B supply voltage than indicated, best multiplier operation occurs, in general, with high driving voltage, high developed bias, and with tank circuits having very low capacitance. In order to obtain maximum power output at high frequencies, the value of the grid-No. 2 resistor should be adjusted so that the full rated value of 250 volts is applied to grid No. 2.

The plate circuit efficiency of this tube is sufficiently good to allow application of full power input at frequencies up to 175 Mc. It is important to note that above 125 Mc, greater power gain is obtained when the tube is used as a doubler than as a straight-through neutralized amplifier because loading of the driving stage due to the input resistance of the 5763 is less severe at the lower frequency.

Because of its low value of output capacitance, two 5763's may be used to advantage in the "push-push" doubler circuit shown in Fig. 4. A single 5763 used as a tripler will provide more than adequate driving power, making a combination which is especially suitable for a low-power transmitter. Fig. 2 also shows a chart of measured power output as a function of operating frequency (solid lines) similar to that shown for the single multiplier (dotted lines).

Because the grid-No. 2 dissipation of this beam pentode will increase rapidly when the excitation is increased, especially with an unloaded amplifier, the maximum allowable grid No. 2 input of 2.0 watts must not be exceeded. Tubes can be quickly ruined if this rating is not adhered to.

Because of the high amplification factor of the 5763, a small cathode resistance of 62 ohms can furnish sufficient voltage to protect the tube in the event of temporary excitation failure and resultant loss in bias developed across the grid resistor. The cathode bias of 5.0 volts required for protection is sufficiently small to make the loss in dc plate voltage negligible.



R** 75,000Ω, 1W FOR DOUBLER; 100,000Ω, 1W FOR TRIPLER
RFC* RF CHOKE, #24 ENAMEL-COVERED WIRE CLOSE WOUND ON RESISTORS

Fig. 1A. Frequency multiplier circuit diagram using the RCA-5763.

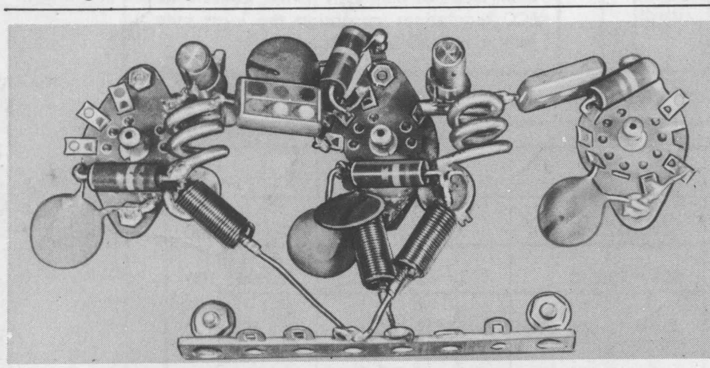


Fig. 1B. Photograph showing an actual model of a frequency multiplier constructed from the above diagram. Note that the placement of parts follows closely the position indicated in the diagram for the purpose of keeping leads as short as possible.

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T. A. 'PAT' PATTERSON, W2VBL .... Editor

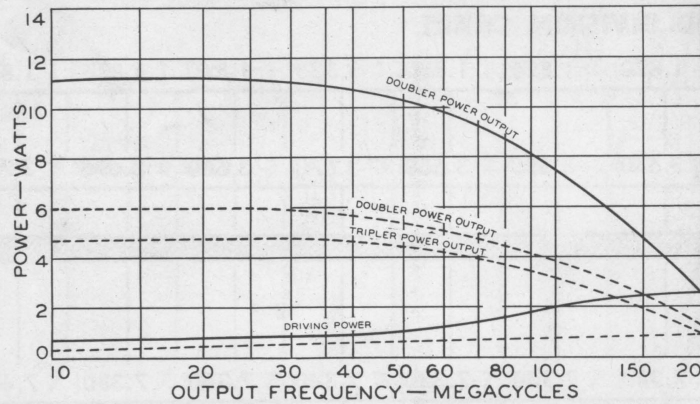
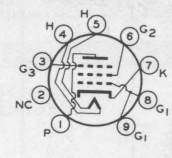


Figure 2. Useful power output of the RCA-5763 as a function of operating frequency in the circuit of Fig. 1A (dotted lines). The solid lines indicate the useful power output of RCA-5763's as a function of operating frequency in the push-push circuit of figure 3.

BASE CONNECTIONS AND TYPICAL OPERATION:

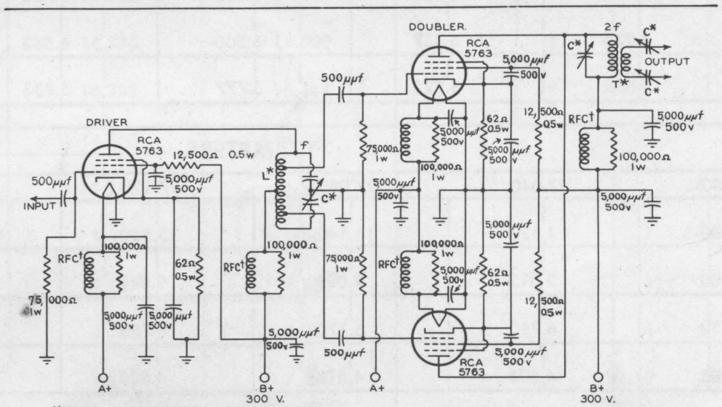


RCA-5763

Figure 3.

	Doubler to 175 Mc	Tripler to 175 Mc	
DC Plate Voltage	300	300	volts
Grid No. 3	Tied to cathode at socket		
DC Grid-No. 2 Voltage	*	*	volts
DC Grid-No. 1 Voltage	–75	–100	volts
From a Grid-No. 1 resistor of	75000	100000	ohms
Peak RF Grid-No. 1 Voltage	95	120	volts
DC Plate Current	40	35	ma
DC Grid-No. 2 Current	4.0	5.0	ma
DC Grid-No. 1 Current (Approx.)	1.0	1.0	ma
Driving Power (Approx.)	0.6	0.6	watt
Power Output (Approx.) #	3.6	2.8	watts

* Obtained from plate supply voltage of 300 volts through a series resistor of 12500 ohms.
# Useful power output is approximately 2.1 watts for doubler service and 1.3 watts for tripler service.



* VALUES DEPENDENT ON OPERATING FREQUENCIES
RFC† RF CHOKE, #24 ENAMEL-COVERED WIRE CLOSE WOUND ON RESISTORS

Figure 4. Circuit diagram of the Push-Push Doubler using a pair of RCA-5763's.

RCA Ham Tips

PUBLISHED - IN - THE - INTEREST - OF - RADIO - AMATEURS - AND - EXPERIMENTERS

VOLUME X, No. 1 | RCA TUBE DEPARTMENT, HARRISON, N. J. | JAN.-MARCH, 1950

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6AX5GT	*Full-wave, high-vacuum rectifier with 6.3 v heater*	1.35
6BQ6GT	*Beam power amplifier for TV horizontal deflection*	3.20
6CB6	*Miniature high-grain pentode amplifier for TV*	2.00
6CD6G	*Beam power amplifier for TV horizontal deflection*	6.00
6S4	*Miniature medium-mu triode amplifier for TV vertical deflection*	1.65
16GP4	*Short 16" metal kinescope*	60.00

HAM DISPLAY GREETS RCA VISITORS

The many visitors to the RCA Home Office during January were greeted by this display. Set up, ready for operation, it gave hundreds of people their first glimpse of a complete amateur radio station. QSL cards displayed were those of some of the many RCA Tube Department employees who are active ham operators. (I have to use the side entrance now—the receptionist still has a sore jaw from answering questions.—Ed.)

ELECTRONIC KEYING SYSTEMS

By MACK SEYBOLD, W2RYI
RCA Tube Department, Harrison, N. J.

Amateurs have been using electron tubes in keying circuits for the past twenty years. As a matter of fact, it was almost that far back when I operated cw on 80-meters with a pair of UX245's in parallel, to key the cathode circuit of an old 210. My recollection of that rig, even though it was a hay-wire bread-board dust-catcher, is very pleasant, and I never did get any key-click complaints from the nearby broadcast listeners or local hams.

Just to get an idea of where that keying circuit had come from, I recently thumbed back through the years of radio journals in my shack. To my amazement, I found dozens of keying circuits for the betterment of ham's estate.

Keying Filters

Among the more complete articles on the subject, there was one by the late Ross Hull. This carefully prepared resume in February, 1929, *QST*, covered all of the major systems in use up to that time. Even today, I'll bet that more than half of the boys on the air are using keying systems that were described in Hull's article. The main components used are chokes and capacitors. In addition to eliminating the sparks at the key contacts, proper utilization of the components in the keyed stage or in the feed lines to that stage minimizes the production of transients in the radiated signal when the key contacts make and break. A typical filter for cathode keying is shown in *Fig. 1*.

Sometimes the old choke and capacitor methods really do accomplish the desired results. But the

Continued on Page 2, Column 1

A SIMPLE CODE-PRACTICE UNIT FOR THE NOVICE

By KEN BUCKLIN, W2CDP
RCA Tube Department

Practice with a soldering iron is as important to the newcomer entering amateur radio as learning the code. The code practice oscillator described helps to accomplish both purposes. It is essential to prepare for the inevitable code test and to develop a good fist; it serves as a practical experiment for the novice; and after the new call letters have been issued, the parts can be put to other useful purposes.

Continued on Page 3, Column 3

"MEET THE GANG"

(First in a series of thumb-nail sketches introducing RCA Tube Department amateurs who contribute to Ham Tips. We hope you enjoy "Meeting The Gang.")

MACK SEYBOLD, W2RYI
ex-W8GGN, W3CQX

Age—35
Employed in—Chemical & Physical Lab, RCA Tube Department, Harrison, N. J.
Home QTH — 14 Gerdes Avenue, West Orange, N. J.
Graduate of—Lehigh University
Active on—2, 10, 20, and 75-meter Phone and cw.
Rig—300 Watts to RCA 813
XYL—Lois
Harmonic—Susy, Age 4½
Articles—Plate Traps—Low-Pass Filters *(QST)*
TVI Shielding—TVI-Proof Rig *(CQ)*
Class-B 807 Modulator and many others (Ham Tips)
Other Hobbies—Photography, Fishing, Boats

KEYING SYSTEMS

Continued from Page 1

tinkering required to clean up a thump or click condition with those systems, and their unreliability under varying conditions, are probably the fundamental causes for all of the additional work that has been done on keying circuits in subsequent years.

Early Electronic Methods

The first complete references that I could find in which vacuum tubes were used to make and break the circuit in the cathode lead of an amplifier were in *QST* for August, 1931. These references were, evidently, the source information for my earliest venture into electronic key-click control. One circuit is shown in *Fig. 2A*, and the *QST* article attributes the original idea to F. B. Kennell of RCA Communications. The immediate proponent of the system, W. H. Hannah, W2US, had remarkable success with the device in his amateur rig.

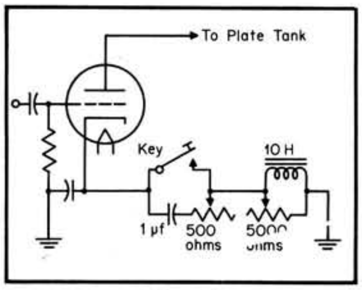


Figure 1

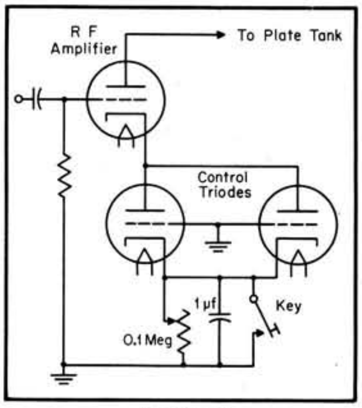


Figure 2A

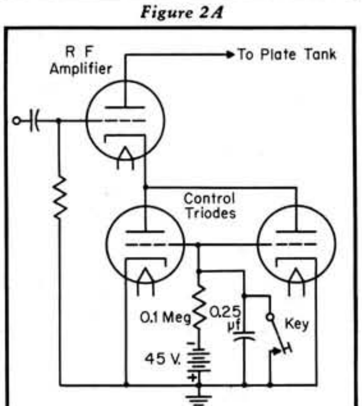


Figure 2B

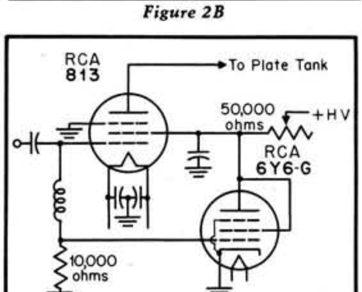


Figure 3

The same issue showed the circuit *(Fig. 2B)* of C. W. Carter, W3AGT, for another electronic key-click control which was the basis for many series-controlled systems which were to follow.

Screen-Grid Transmitting Tubes

During the first few years after power pentodes and tetrodes became available for amateur use, the same general methods that previously had been used for keying triodes were employed. Some of the boys did utilize the screen grid as a keying control element by putting a key or a relay in series with the screen lead, but this method still required the use of key-click filters.

The beginnings of vacuum-tube control of pentode-screen keying seem to have occurred in 1941. In the December *Radio* for that year, W. W. Smith, W6BCX, described "A Substitute for Safety Bias" which utilized a triode shunting the screen of an output tube. Later, F. T. Smith, W1FTX, built a transmitter (Feb. 1947 *QST*) in which a 6Y6-G, triode connected, controlled the screen of an 813. In these screen-shunting systems, an earlier stage is keyed, and the bias developed across the grid-leak of the final amplifier is the voltage which triggers the control tube. A diagram of the W1FTX final is shown in *Fig. 3*.

VR-Tube Keying

My solution to the problem of key-click control has been arrived at from a somewhat different approach, in that voltage-regulator tubes are used. The characteristics of the VR tubes are suited remarkably well for this application and the maximum ratings established for them are not exceeded in this new circuit.

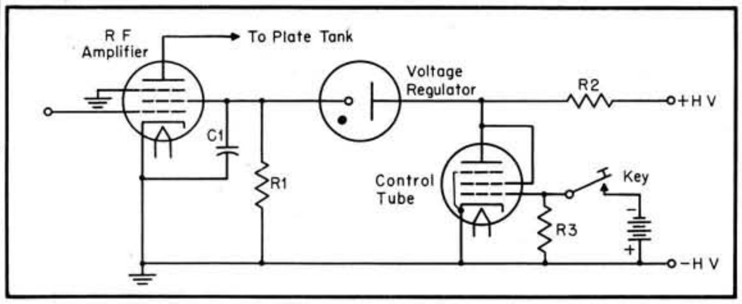


Figure 4

The gaseous atmosphere within a VR tube limits the tube to two major operating states — conducting, and non-conducting. In the conducting state, the current-carrying medium is ionized gas, and the voltage drop between anode and cathode is constant throughout a range of current flow from 5 to 40 milliamperes. In the non-conducting state, when the voltage applied between the anode and cathode falls below the ionizing potential of the gas, the tube virtually is an open circuit. For the 0A3, the voltage required for tube operation is 75 volts. For the 0C3 and the 0D3 it is approximately 105 and 150 volts, respectively. For the miniature types 0A2 and 0B2 it is approximately 150 and 108 volts, respectively.

When one of these tubes, say the 0C3, is placed in the screen supply lead of a pentode or tetrode, the tube will do one of two things: it will conduct or it won't. That, of course, is just what a mechanical key will do. In opposition to the key, however, there are no mechanical components to arc and spark when the circuit opens and closes. In addition, the ionizing and de-ionizing time of the gas within the VR tube causes an infinitesimal time delay which smooths the leading and lagging edges of a keyed character.

Operation

The VR tube in a keying circuit is an effective non-mechanical keying gap. Since the tube needs no filament supply, it can be placed at any convenient point in the screen supply line. The VR tube is controlled by an auxiliary vacuum tube which determines the "on" or "off" conditions. This control tube is activated by applying the correct potential to its grid No. 1 and, since the grid No. 1 is operated at a negative potential, very little current flows in the actual key circuit. Figure 4 shows the basic components of the system.

When the key is down, the bias voltage applied to the control tube prevents it from conducting and the VR tube and the rf amplifier conduct current through R_2. The supply voltage, minus the drops across R_2 and the VR tube, is the effective screen-grid potential applied to the rf amplifier and permits normal key-down operation. When the key is up, the bias on the control tube drops to zero, making it conduct and, as a result, the voltage drop across it becomes lower than the required ionizing potential for the VR tube. The VR tube, therefore, stops conducting, the supply voltage is com-

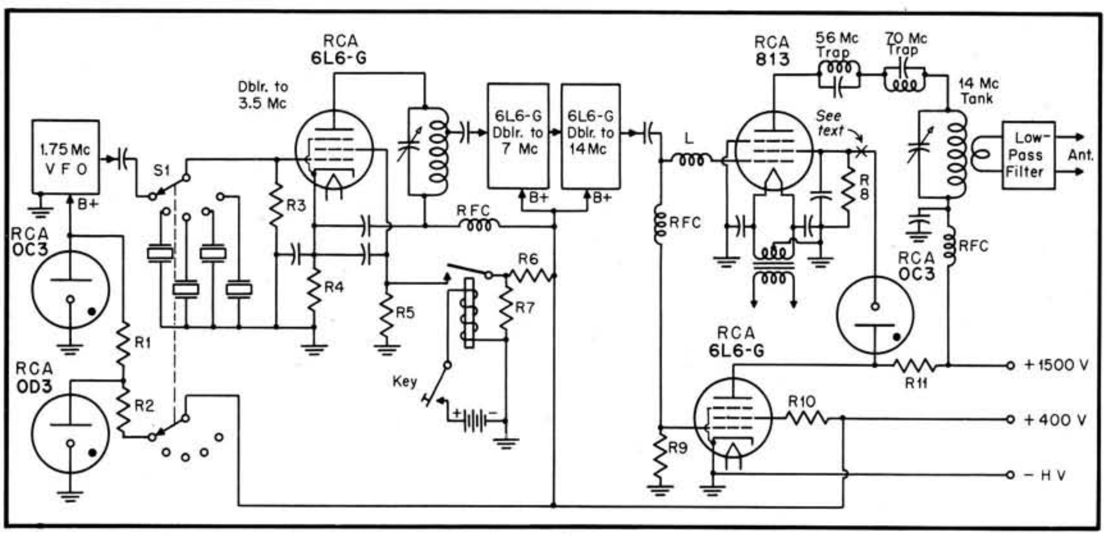


Figure 6

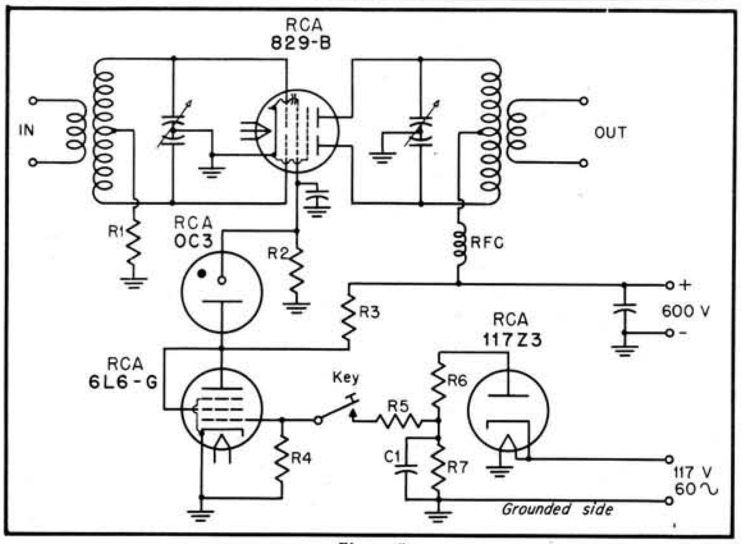


Figure 5

pletely removed from the screen-grid of the rf amplifier, and the transmitter goes off the air.

This procedure can be repeated as often as desired, as in cw work; the rapidity of keying is limited only by the ionizing and de-ionizing characteristics of the VR tube. In the circuit of *Fig. 4*, the resistors R_1 and R_3 are high in value, and are present merely to maintain each grid at a potential near zero when keying potentials are removed. C_1 is a conventional rf by-pass capacitor.

Transmitter Circuits

A practical application of the system is shown in *Fig. 5*. Here an 829-B final is keyed with an 0C3 controlled by a 6L6-G. Cutoff bias for the 6L6-G is obtained from a 117Z3 as shown, or it can be taken from any type of supply capable of furnishing 125 volts of bias.

Another application of the VR tube keying circuit is shown in *Fig. 6*. This arrangement makes it possible to key a buffer stage or the oscillator so that break-in keying may be utilized. Bias for the control tube is obtained automatically at the correct time from the grid resistor of the final amplifier. The protection the control tube gives to the final amplifier, if excitation fails or when doubler and buffer stages are being adjusted, makes this keying system a valuable adjunct to a beam power or pentode final. (On higher-powered finals, a huskier beam power tube must be used as a control tube.)

One additional component has been added to the circuit by Bill Scherer, W2AEF. This addition is a 5-henry choke placed in series with the screen lead at the point marked "X". The choke was added to give a more rounded leading edge to the keyed character. Further details on this addition may be found in Scherer's article, "The Gold-Plated Special," in *CQ*, October, 1948.

For those who wish to design an amplifier operating under conditions other than those shown here, a detailed description of the system is given in "VR Tube Keying Circuits," which appeared in the May, 1948 issue of *CQ*. Another version of the system is described in "A TVI-Free Transmitter for 10 Meters" which was published in *CQ* for October and November, 1949.

If clickless keying is desired, the VR tube keying system is a straightforward answer to a problem that has been confronting hams since the days of the spark transmitter.

PARTS LIST

Fig. 5
- C_1 = 3.0 uf, 150 working volts
- R_1 = 5800 ohms, 2 watts
- R_2, R_4 = 0.25 megohm, 0.5 watt
- R_3 = 10,000 ohms, 50 watts
- R_5 = 50,000 ohms, 0.25 watt
- R_6 = 100 ohms, 0.5 watt
- R_7 = 0.1 megohm, 0.5 watt

Fig. 6
- L = 0.5 henry, grid choke
- R_1 = 1250 ohms, 5 watts
- R_2 = 4400 ohms, 20 watts
- R_3 = 0.1 megohm, 0.5 watt
- R_4 = 1000 ohms, 10 watts
- R_5, R_7 = 0.25 megohm, 0.5 watt
- R_6 = 20,000 ohms, 5 watts
- R_8 = 7500 ohms, 5 watts
- R_9 = 0.5 megohm, 0.5 watt
- R_{10} = 35,000 ohms, 100 watts
- R_{11} = 50,000 ohms, 5 watts

RF components and bypass capacitors are conventional.

TYPE DESIGNATIONS

The following dual type designations are being dropped in favor of single identification. As stocks of double-branded tubes are exhausted, single branded tubes will take their places. There is no change in tube characteristics or quality.

Old Brand	*New Brand*
1B3GT/8016	1B3GT
6AB7/1853	6AC7
6AC7/1852	6AB7

CODE-PRACTICE OSC

Continued from Page 1

The code oscillator is mounted on a wood board and is complete except for headphones. A 1½-volt radio "A" cell (RCA-VS036) serves to heat the 50-milliampere filament of the 1A5-GT, and a very small 45-volt "B" battery (RCA-VS055) is adequate to supply power to the plate of the tube, which draws only ½ milliampere. The transformer and circuit were chosen to provide good volume for the phones at low battery drain.

The 1A5-GT is a pentode, connected as a triode (with screen tied to plate) in a Hartley-type oscillator circuit. When the transformer is mounted, washers or some other type spacers should be used to provide clearance between the base of the transformer and the baseboard for the transformer leads. The batteries are held with wires fastened to the baseboard by means of soldering lugs and woodscrews. The connections to the 1½-volt VS036 are soldered. A standard snap-type battery plug is used for the 45-volt VS055.

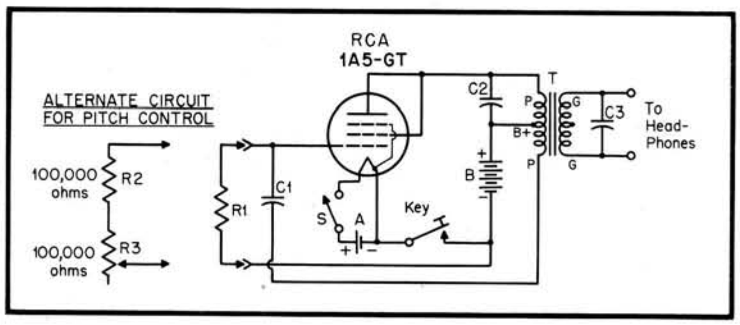
Pitch Control

No provision was made in this model for changing the tone of the oscillator, but a pitch or frequency control can be added if desired. This control is a 100,000-ohm potentiometer (such as an ordinary volume control) which, in series with a 100,000-ohm fixed resistor, replaces the 180,000-ohm resistor. An on-off switch on the pitch control may replace the knife switch(S).

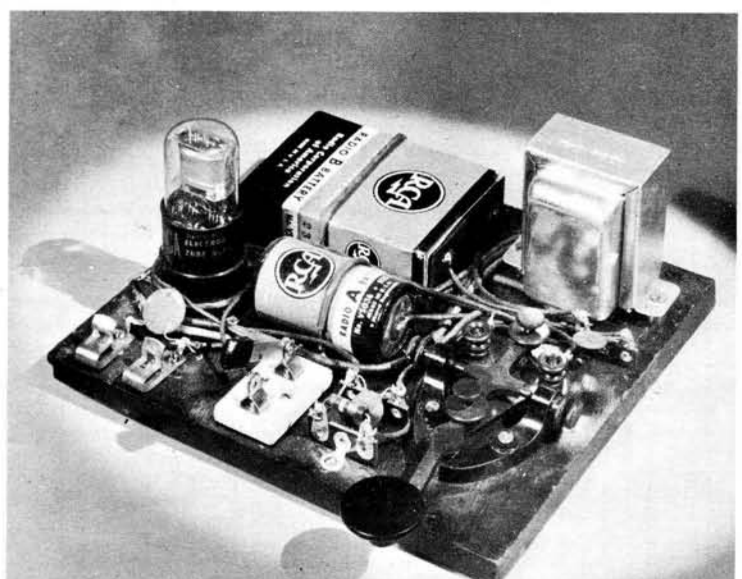
With this code practice oscillator, several headphones may be used in series, or an amplifier may be connected in place of the phones. The tone is very good, and is much more pleasing and realistic than that obtained with a buzzer.

PARTS LIST

- R_1 = 180,000 ohms, 0.5 watt
- R_2 = 100,000 ohms, 0.5 watt
- R_3 = Pitch control potentiometer, 100,000 ohms, 0.5 watt
- C_1, C_3 = 0.005 uf, Sprague disc ceramic
- C_2 = 0.001 uf, Sprague disc ceramic
- S = SPST knife switch
- T = Audio interstage transformer, push-pull plates to push-pull grids, Thordarson T20A24 or equivalent
- A = "A" battery, 1½ volts, RCA-VS036
- B = "B" battery, 45 volts, RCA-VS055
- Socket = Panel-mounting type Eby 12-8 octal



Wiring diagram of the code-practice oscillator.



Completed code-practice oscillator is simple and compact. (Those RCA Batteries last longer!)

SIMPLE OVER-MODULATION INDICATOR

By George Hanchett, W2YM
RCA Tube Dept., Harrison, N. J.

This simple and inexpensive over-modulation indicator is a useful piece of equipment which enables the amateur to comply with the FCC requirements for amplitude-modulated transmitters. It consists essentially of a high-voltage rectifier, type 1B3-GT, a 50-ohm potentiometer R, and a small neon glow lamp (NE45). A diagram of this indicator connected into a typical class C modulator stage is given in *Fig. 1.* Filament voltage for the 1B3-GT is obtained from the drop across the potentiometer R. This potentiometer is calibrated, as described below, in milliamperes of plate current so that when once the final has been adjusted, the proper filament voltage can be applied to the 1B3-GT. The 1B3-GT can be used with any transmitter in which the final plate current exceeds 225 milliamperes. Transmitters having a final plate current of less than 225 milliamperes may use a tube such as the 3V4 diode-connected (grid No. 1 tied to filament mid-tap; grid No. 2 tied to plate) provided the plate supply voltage does not exceed 600 volts.

When the amplitude of the modulation voltage drives the instantaneous plate voltage of the modulated amplifier to a value negative with respect to B— the rectifier conducts allowing the neon lamp to glow and, thus, to indicate over modulation.

Adjustment and Use

When the transmitter is being adjusted, potentiometer R should *always* be set so that there is no voltage on the filament of the 1B3-GT. This precaution is necessary to prevent damaging the tube. After the transmitter adjustments are completed, the plate current of the modulator stage is measured and the potentiometer R set accordingly. In the circuit shown in *Fig. 1,* the neon lamp will glow when the rectified voltage is approximately 75 volts. If indication of 100-per-cent modulation is desired, the bleeder tap should be set at 75 volts. If it is desired that modulation percentages of less than 100 per cent be indicated, the following equation should be used for calculating the position of the voltage tap on the bleeder. (See Figure 3)

Calibrating Potentiometer R

Potentionmeter R may be calibrated, as shown in *Fig. 2,* by means of a 6-volt battery, a 25-ohm (25-watt) variable resistor Rs, and a meter. Adjust the variable resistor Rs to provide a definite value of current, say 300 milliamperes on meter A, and then adjust potentiometer R so that the voltage applied to the filament of the 1B3-GT is 1.25 volts. Because there is slight interaction resulting from the position of the variable arm of R, a few further adjustments of Rs and R may be necessary to obtain correct voltage and current readings. Rs is then set for different values of current and R is again adjusted to obtain the proper filament voltage. After sufficient readings are taken, a curve of final plate current versus dial reading for correct filament voltage may be plotted for future reference.

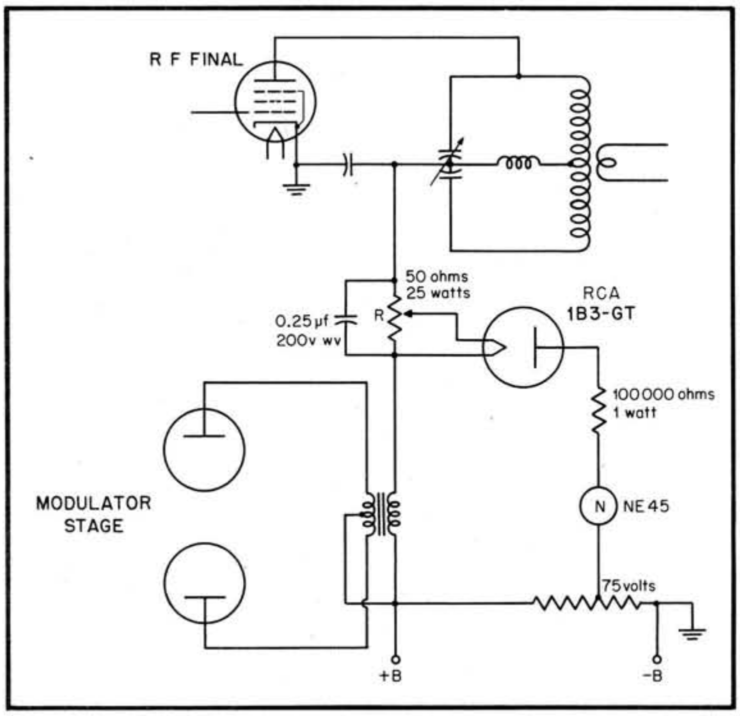


Figure 1

UP TO 3000 MC!

Another "RCA First" in advanced tube design . . . the RCA-5675 "Pencil Type" triode for UHF applications is typical of RCA engineering leadership in developing new and better tubes for communcations and industry. The Fountainhead of Modern Tube Development is RCA.

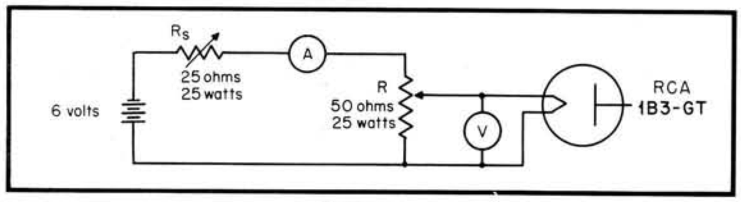
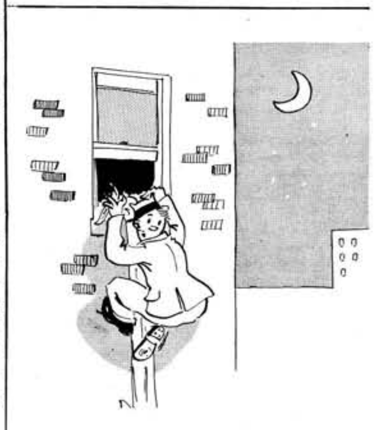


Figure 2

$$\frac{\%\ \text{modulation}}{100} = \frac{\text{Total bleeder voltage} - \text{tap voltage} + \text{glow lamp voltage}}{\text{total bleeder voltage}}$$

Figure 3



Getting Out OK!

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T. A. 'PAT' PATTERSON, W2VBL .... *Editor*

HAM TIPS

A PUBLICATION OF THE TUBE DEPARTMENT · RCA · HARRISON, N. J.

Volume X, No. 2 Spring, 1950

A Panoramic Adaptor with a Circular Base Line

By W. E. Babcock*

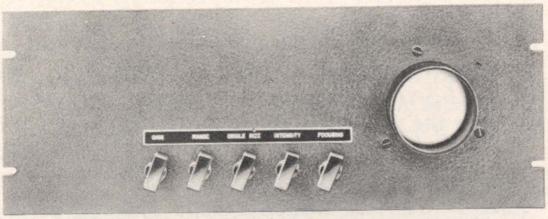


Figure 1. Panel view of the circular base line panadaptor showing position of the front controls and C R tube face.

SIMULTANEOUS visual reception of a large number of radio signals over a broad band of frequencies is provided by the panoramic adaptor. It may be used with almost any type of receiver and provides an indication of the frequency, type, and strength of all signals within a given bandwidth (centered at the frequency to which the receiver is tuned). When used to spot unoccupied channels in the band it can be an invaluable aid in avoiding interference problems. When used with a calibrated scale it becomes an accurate frequency meter. The amateur who owns a panoramic adaptor will no doubt find many additional uses for it.

Basically, a panoramic adaptor is a superheterodyne receiver with a broadly tuned r f stage and a narrow-band i f stage. However, in the conventional superheterodyne receiver, the local oscillator is fixed in frequency at any one time, while in the panoramic adaptor, the local-oscillator is frequency modulated over a given band. In commercial panoramic adaptors, all signals within the bandwidth covered by the r f stage are shown on a cathode-ray tube as vertical "pips" on a horizontal base line. In the panoramic adaptor described here (and shown in Figure 1), a circular base line is used on which signals appear as radial pips extending toward the center of the screen. The frequency of any signal appearing as a pip on the screen is determined by the position of the pip on the circumference of the circle as shown in Figure 2. The center frequency (to which the companion receiver is tuned) is shown at zero, while other signals are shown in proper frequency relationship to this zero.

*Application Engineering, RCA Tube Dept., Harrison, N. J.

General Circuit Description

A circuit diagram of the panoramic adaptor is given in Figure 5. The signal input to the adaptor is taken from the plate of the converter tube in the receiver. The 6AU6 r f stage is tuned to the intermediate frequency of the receiver and has a rising frequency characteristic either side of the center frequency to compensate for the drooping frequency characteristic resulting from the selectivity of the r f stage in the receiver. The plate circuit of the 6BE6 mixer stage is tuned to 160 kc, while the oscillator section is varied over a range of 50 kc above and below 616 kc (456 kc, the usual receiver i f, + 160 kc) at a rate of 60 times per second. The sawtooth voltage driving the reactance modulator tube, and the circular sweep voltage for the cathode-ray tube are both derived from the 60-cycle line voltage.

Plate and screen voltages for all tubes except the cathode-ray tube are obtained from a conventional full-wave rectifier. The screen voltage for the reactance modulator tube is held constant at 150 volts by the OA2 voltage regulator tube. The anode voltage for the cathode-ray tube is obtained from a voltage-doubler circuit in which the output voltage is added to that from the full-wave rectifier to give a total second-anode voltage of approximately 1100 volts. **This high voltage is dangerous.** Extreme care must be exercised if it is necessary to work on the adaptor with the power on. Be sure the high voltage filter capacitors are discharged when making tests with the power off.

Use of Standard Components

All components used in the construction of the panoramic adaptor are standard receiver replacement components. Many hams will no doubt have many of the parts on hand. The transformers used in the i f stages are designed to tune to 175 kc. However, their tuning range is such that they may easily be tuned to 160 kc. Maximum width of the pips obtained when these transformers are used is approximately 5 kc at the base line. This bandwidth is sharp enough for observing signals differing by less than 5 kc.

Construction and Layout Details

The adaptor is constructed on a 10"x14"x3" chassis with a standard 7"x19"x1/8" rack mounting panel. Figures 3 and 4 illustrate the chassis layout. No special precautions are required in constructing the adaptor other than those normally practiced in constructing receiver i f stages. The cathode-ray tube, of course, should be mounted as far from the power transformer as possible to minimize hum pickup on the deflection plates. If difficulty is experienced with hum pickup on the grid of the cathode-ray tube, it may be necessary to add a 4-μf capacitor (C_{32}) from the cathode of the 3KP1 to the arm of the intensity control.

Auxiliary Use

For the station that does not have a modulation monitor, the cathode-ray tube in the panoramic adaptor can be used for this purpose. For this use, capacitors C_{28}, C_{29}, C_{30}, and C_{31} should be connected by means of a 4-pole double-throw relay so they will connect the deflection plates of the cathode-ray tube to the plates of the deflection amplifier tubes in the adaptor on "receive" and to the r f and modulating voltages of the transmitter on "transmit." The coupling to the transmitter should be such that the voltage ratings of C_{28}, C_{29}, C_{30}, and C_{31} are not exceeded. For more detailed information on the use of a cathode-ray tube as a modulation indicator, see Ham Tips of January-April, 1948.

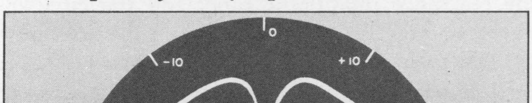


Figure 2. The position of the pips on the circumference of the circle indicates the frequency of the received signals.

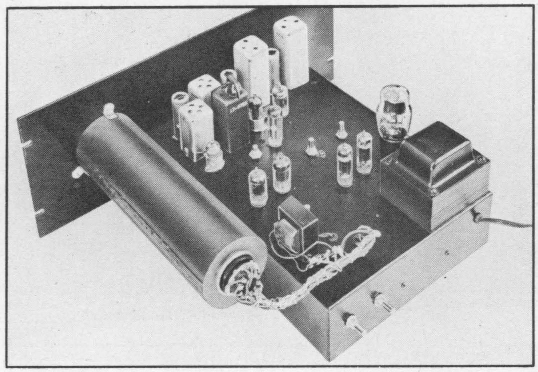


Figure 3. A bird's eye view of the panadaptor illustrates the chassis layout. The cylindrical sleeve supports the c-r tube.

Alignment Procedure

Variable resistor R_{35} and capacitor C_{26} form a phase-shifting network which applies two sinusoidal voltages 90° out of phase to the push-pull grids of the deflection amplifiers. R_{35} should be varied until the best circle is obtained. A separate 6.3-volt filament transformer is used to supply the voltage to the phase-shifting network. It would be possible to supply this voltage from the filament winding of the power transformer, except that any heater-cathode leakage in the tubes would result in spikes being superimposed on the heater voltage and consequent distortion of the circle. If the line voltage has a perfect sinusoidal wave form, the circle on the screen of the cathode-ray tube will be very nearly perfect. Although in most cases, the line voltage will vary slightly from a perfect sine wave, the resulting pattern will still be very nearly a circle.

During alignment of the i f stage, a high-impedance dc voltmeter, such as an RCA Voltohmyst*, is connected across the detector load resistance (R_{14}). With R_{22} set at zero, a 160-kc signal from a signal generator is applied to the signal grid (grid No. 3) of the 6BE6 and the i f transformers are peaked for maximum dc voltage across the detector load resistance.

Variable capacitor C_{14} controls both the magnitude and phase of the r f voltage appearing at the control grid of the reactance tube. Its setting is not critical, but during the adjustments described in the following paragraph, it should be set near maximum capacitance. If it is desired to increase the frequency range of the adaptor, at a sacrifice of linearity, approximately 50 kc more deviation may be obtained by setting C_{14} to maximum capacitance.

Sweep padder, R_{21} is used to set the amplitude of the sawtooth voltage obtained from the plate of the sawtooth generator so that the total frequency deviation of the local oscillator is exactly 100 kc when R_{22} is at maximum. It should initially be set at about half scale. The center fre-

*Reg. Trade Mark, U. S. Pat. Off.

quency f_0 should be set to the proper value (616 kc if the companion receiver has an i f of 456 kc). Capacitors C_A and C_B which are contained in oscillator transformer T_3 are used to set f_0. C_A is a coarse tuning adjustment which may be turned with a screw driver; C_B is a fine tuning adjustment controlled by a knob at the top of T_3. However, R_{20} in the cathode circuit of the reactance tube will also have a slight effect on f_0. R_{20} is used to set the cathode bias of the reactance tube so that the frequency deviation of the oscillator is linear. It should be set initially to give a cathode-to-ground voltage of approximately 2 volts. With control R_{22} set at minimum and with a 456-kc signal applied to the signal grid of the mixer stage, C_B is then adjusted to give maximum dc voltage across R_{14}. Control R_{22} is then set at maximum. A pip, corresponding to the 456-kc input signal, will now appear on the screen of the cathode-ray tube. The tube may be rotated so that this pip appears at the top of the screen. The signal generator frequency should now be shifted 50 kc above and below the center frequency of 456 kc. The pip will be seen to rotate around the circle as the frequency is shifted. When the deviation of the local oscillator is set to exactly ± 50 kc, the pip will travel almost the full 360° of the circle as the signal-generator frequency is shifted from 406 to 506 kc. If the pip moves around the circle before the range is covered, the sawtooth voltage applied to the grid of the reactance tube is not great enough and the resistance of sweep padder R_{21} should be decreased until the proper frequency range is covered. If too great a range is covered, the resistance of R_{21} should be increased.

Linearity and Bandwidth

Approximately 10° at the bottom of the circle is taken up by the retrace of the sawtooth voltage driving the reactance tube. During this interval, the local oscillator is being frequency-modulated 50 kc each side of f_0 in the same manner as during the rising portion of the sawtooth, except that the deviation is in the opposite direction and occurs in a much shorter time. This deviation causes a small pip to appear at the bottom of the circle whenever a signal is applied to the adaptor. Since this pip occupies such a small portion of the circle (approximately 10°), it will appear to remain stationary as the input signal frequency is varied. It may be used as a dividing marker between 406 and 506 kc.

After the frequency deviation of the local oscillator is set to the proper value, the linearity of the deviation should be checked. If the deviation is linear, half the circle will be traced for a 50-kc frequency change of the signal generator. If either more or less than half the circle is traced, R_{20} should be adjusted slightly. Since any adjustment of R_{20} causes a slight shift in f_0, the setting of C_B must be changed to correct it. If the linearity is poorer, the adjustment of R_{20} has been in the wrong direction. After R_{20} is set for best linearity, it may be found that the frequency range covered has changed and R_{21} will have to be adjusted also.

Capacitors C_1 and C_5 are used to overcouple the r f transformers and thus give a rising frequency characteristic each side of the center frequency (456 kc for most receivers). The primaries of T_1 and T_2 are tuned approximately 10 kc below the maximum frequency to be received (496 kc). The secondaries of T_1 and T_2 are tuned approximately 10 kc above the lowest frequency to be received (416 kc). Approximate alignment is obtained by applying a 496-kc signal from a signal generator to the input of the adaptor and adjusting the primaries of T_1 and T_2 for maximum deflection on the screen of the cathode-ray tube. The signal-generator frequency is then changed to 416 kc and the secondaries of T_1 and T_2 adjusted for maximum deflection.

Final Alignment

The final alignment should be done with the adaptor connected to the plate of the converter tube in the receiver with which it will be used by means of a 47,000-ohm isolating resistor (R_A). This resistor should be connected as close to the converter plate as possible and a shielded lead used between the resistor and the adaptor input. With the receiver tuned to approximately 3 Mc, set the signal generator to the same frequency and tune the receiver until the signal appears as a deflection at the top of the screen. Then change the signal generator frequency 50 kc higher, moving the deflection clock-wise to the bottom of the screen. Adjust the trimmers on T_1 and T_2 until

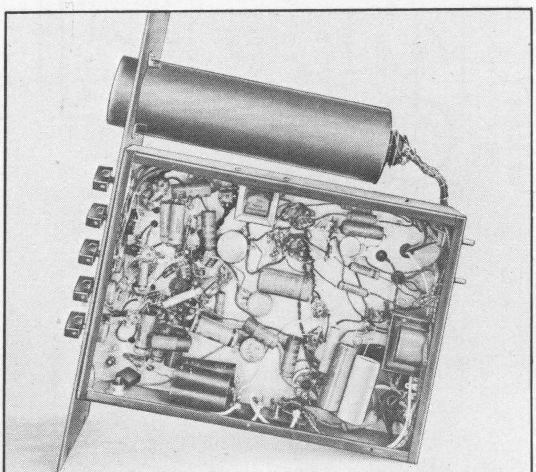


Figure 4. Placement of components and wiring on the under-chassis of the panadaptor reveals compactness without crowding.

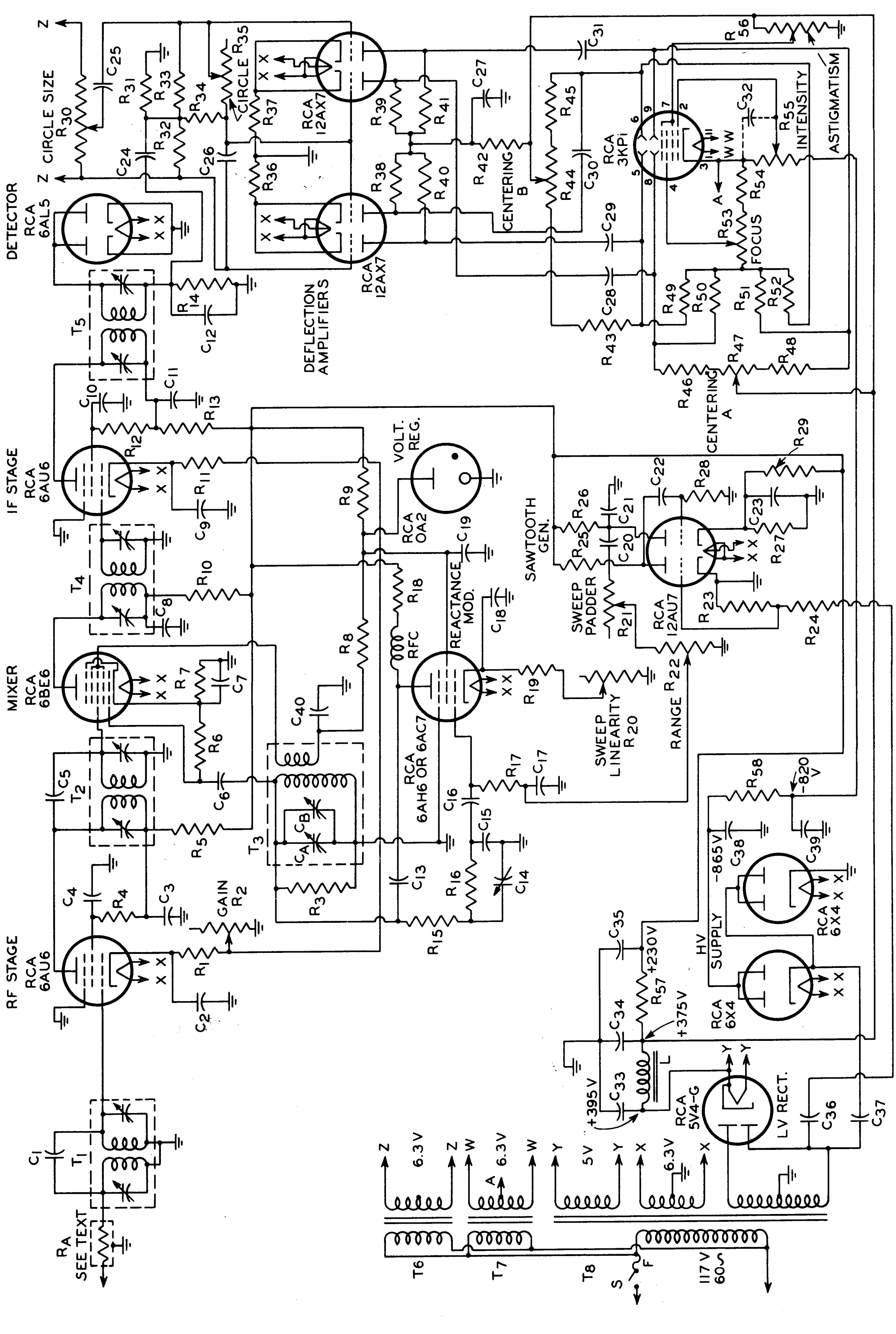


Figure 5. Schematic of the panadaptor.

the amplitude of the deflection is approximately the same as it was at the center. Then change the signal generator frequency 50 kc lower, moving the deflection counterclockwise to the bottom of the screen. Again adjust the trimmers to make the amplitude of the deflection approximately what it was at the center. This second adjustment will upset the first adjustment, and it will be necessary to go back and forth and to compromise on adjustments in order to make the gain as nearly uniform as possible over the entire 100-kc range.

Alignment for Other Frequencies

The r f stage of the adaptor may be aligned for center frequencies from about 420-500 kc. If the companion receiver has an intermediate frequency different from 456 kc, but falling within the 420-500 kc range, the alignment procedure is exactly as given above, except that it is necessary to correct the alignment frequencies of the r f stage and the local oscillator.

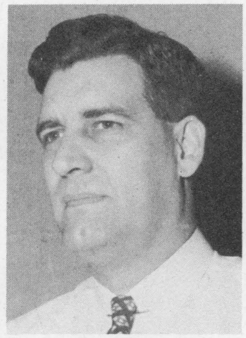
Calibration of Scale

If accurate frequency readings are desired a calibrated scale may be made up on lucite or other transparent material and placed in front of the cathode-ray tube screen. The scale may be calibrated using a signal generator to determine the desired calibration points. When the signals are obtained directly from a signal generator, it should be remembered that signals from 456 kc to 506 kc will appear on the left half of the circle, while signals from 456 kc to 406 kc will appear on the right half. When the signals are obtained from the output of the converter tube in the receiver, signals up to 50 kc above the receiver frequency will appear on the right half of the circle and signals up to 50 kc below the receiver frequency will appear on the left half.

RCA HAM TIPS is published by the RCA Tube Department, Harrison, N. J., and is made available to Amateurs and Radio Experimenters through RCA tube and parts distributors.

MEET THE GANG

GEORGE E. JONES, JR.



W2CBL since 1930
ex-W9BDJ since 1922
Age: 41
Employed in: Equipment Section, RCA Tube Department, Harrison, N. J.
Home QTH: 71 Lincoln Drive, Rochelle Park, N. J.
Graduate of: Kansas University '30.
Active on: 20 and 80 phone & cw.
Rig: 350 watts to pair RCA 812-A's.
XYL: Jean.
Harmonics: George—age 10, Phyllis—age 6.
Articles: DeLux 812-A Bandswitching Transmitter—Ham Tips.
Other Hobbies: Model railroads and table tennis.

PARTS LIST

C1, C5	47-uuf ceramic
C2, C3, C7, C8, C10, C11, C28, C29, C30, C31, C40	0.01-uf 400 V paper
C4, C9, C18, C25	0.1-uf 400 V paper
C6	68-uuf ceramic
C12, C13	470-uuf mica
C14	1—10-uuf ceramic trimmer
C15	15-uuf mica
C16	100-uuf 600 V paper
C17	270-uuf mica
C19	0.006-uf 400 V paper
C20	0.25-uf 400 V paper
C21, C22, C27, C36, C37	0.1-uf 600 V paper
C23	25-uf 25 WV electrolytic
C24	0.03-uf 400 V paper
C26	1-uf 600 V paper
C32	4-uf 150 WV electrolytic
C33, C34	16-uf 450 WV electrolytic
C35	40-uf 450 WV electrolytic
C38, C39	0.1-uf 2000 V paper
RA	47,000 ohms, in receiver connected to plate of converter tube
R1	100 ohms
R2	10,000 ohm potentiometer—linear taper
R3	51,000 ohms
R4, R12	22,000 ohms
R5, R10	4700 ohms 1 watt
R6	24,000 ohms
R7	150 ohms
R8	6800 ohms
R9	2200 ohms 5 watt
R11, R19	100 ohms
R13	3300 ohms 1 watt
R14	680,000 ohms
R15	20,000 ohms
R16	100,000 ohms
R17, R31, R32, R33, R34, R58	220,000 ohms
R18	3000 ohms 1 watt
R20	500,000 ohm potentiometer—linear taper
R21, R44, R47, R56	1 megohm potentiometer—linear taper
R22	100,000 ohm potentiometer—linear taper
R23, R24, R25, R26, R28, R54	1 megohm
R27	4700 ohms
R29	51,000 ohms 2 watt
R30	20 ohm potentiometer, 5 watt
R35	5000 ohm potentiometer—linear
R36	270 ohms
R37	390 ohms
R38, R39, R40, R41	27,000 ohms
R42	3300 ohms
R43, R45, R46, R48	3.9 megohms
R49, R50, R51, R52	20 megohms
R53	2 megohm potentiometer—linear taper
R55	0.5 megohm potentiometer—logarithmic taper
R57	2500 ohms, 10-watt
T1	456-kc i f transformer; Meissner 16-5740 or equiv.
T2	456-kc i f transformer; Meissner 16-5742 or equiv.
T3	Oscillator transformer; Meissner 17-6753 or equiv.
T4	175-kc i f transformer; Meissner 16-6649 or equiv.
T5	175-kc i f transformer; Meissner 16-6651 or equiv.
T6, T7	Filament transformer 6.3 volts, 1 amp; Thordarson T21F08 or equivalent
T8	Power transformer 350-0-350 volts 120 ma;—6.3 volts, 4.7 amp; 5 volts, 3 amp; Thordarson TS-24R05 or equivalent
S	SPST switch (mounted on R55)
F	Fuse
RFC	RF choke 30 mh
L	Filter choke—8 henrys—150 ma Thordarson T-20C54 or equivalent

All resistors 0.5 watt unless otherwise specified.

HAM TIPS

RCA

A PUBLICATION OF THE TUBE DEPARTMENT · RCA · HARRISON, N. J.

A Panoramic Adaptor with a Circular Base Line

By W. E. Babcock*

Figure 1. Panel view of the Circular Base Line Panadaptor showing position of the front controls and C R tube face.

SIMULTANEOUS visual reception of a large number of radio signals over a broad band of frequencies is provided by the panoramic adaptor. It may be used with almost any type of receiver and provides an indication of the frequency, type, and strength of all signals within a given bandwidth (centered at the frequency to which the receiver is tuned). When used to spot unoccupied channels in the band it can be an invaluable aid in avoiding interference problems. When used with a calibrated scale it becomes an accuracy frequency meter. The amateur who owns a panoramic adaptor will no doubt find many additional uses for it.

Basically, a panoramic adaptor is a super- ... a broadly tuned r f stage ... in the

as a pip on the screen is determined by the position of the pip on the circumference of the circle as shown in Figure 2. The center frequency (to which the receiver is tuned) is shown at zero, while other signals are shown in proper frequency relationship to this zero.

General Circuit Description

A circuit diagram of the panoramic adaptor is given in Figure 3. The signal input to the adaptor is taken from the plate of the converter tube in the receiver. The 6AU6 r f stage is tuned to the intermediate frequency of the receiver and has a rising frequency characteristic either side of th center frequency to compensate for the droop frequency characteristic resulting from the se tivity of the r f sp-stage in the receiver. The p circuit of the 6BE6 mixer stage is tuned to kc, while the oscillator section is varied ove range of 50 kc above and below 616 kc (456 the usual receiver i f, + 160 kc) at the rate of 6 times per second. The sawtooth voltage driving the reactance modulator tube, and the circular sweep voltage for the cathode-ray tube are both derived from the 60-cycle line voltage.

Plate and screen voltages for all tubes except the cathode-ray tube are obtained from a conventional full-wave rectifier. The anode voltage ... cathode-ray tube is obtained from a

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HAM TIPS

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Volume X, No. 3 Fall, 1950

Design and Application of High-Pass Filters

By

Mack Seybold, W2RYI*

Although filter theory is apt to be appreciated by the advanced amateur, the average ham prefers to avoid the subject because of the mathematics involved. If you would like to build a high-pass filter for your TV set to preserve peace in the family or to assist a neighbor in obtaining adequate low-frequency rejection in his receiver, this is the dope you have been waiting for. Easy-to-build filters are fully described.

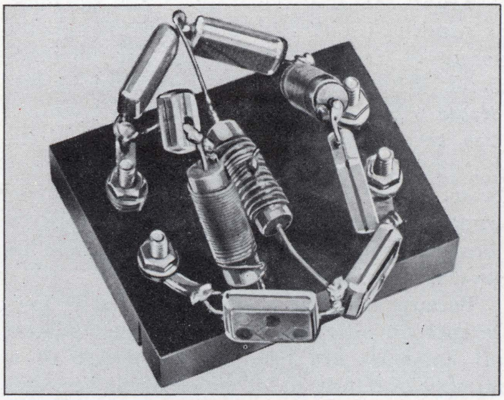

Fig. 1. A two-section, series-derived filter which can be connected to the antenna terminals on the TV receiver.

THE causes of interference to television reception encountered when an amateur station is transmitting can be divided into three classifications: harmonic radiation from the transmitter, generation and radiation of harmonics by external non-linear devices** excited by the amateur signal, and incomplete rejection of the amateur fundamental signal by the television receiver. If an amateur transmitter has been TVI-proofed, and if the external producers of detrimental harmonic radiation have been eliminated, then most of the remaining interference difficulties can be attributed to inadequate receiver rejection.

Television receivers vary in ability to reject low-frequency signals. Some have a tuned rf stage and a built-in, high-pass filter. In many installations, in the vicinity of amateurs, these require no additional filtering. Some receivers have only a choke input to the rf tube, and no provision for the rejection of strong signals.

If a television receiver does not reject amateur signals from the 80- and 160-meter amateur bands, interference may be produced in the video amplifier. Signals from the 10- and 11-meter bands can produce interference in the if amplifier, and strong signals from practically all amateur bands can produce interference in the "front end" of the television receiver. Most of the difficulties arise in the front end, and the major phenomena involved are blocking, rectification, and heterodyning.

Blocking occurs when a strong extraneous signal reduces the gain of the receiver by taking over the avc action or by driving the control grid of an amplifier tube to a positive potential, thereby producing grid current which biases the stage to a potential at which no amplification can take place.

Rectification occurs in the grid-cathode circuit of an rf amplifier when an extraneous signal swings the grid beyond the linear portion of the tube's characteristic curve. Harmonics are then produced by this action, and they are exact multiples of the frequency of

*RCA Tube Dept., Harrison, N. J.

**Rectifiers, either oxide or thermionic, connected to electrical conductors. Also pipe junctions, air-duct and drain-pipe joints, telephone buttons, corroded ground clamps, radio receivers, etc.

the extraneous signal. When one of these harmonics falls in a television channel, a cross-hatched picture may be produced

Heterodyning occurs when an amateur signal and a second extraneous signal enter the receiver. For instance, a 14-Mc amateur signal can heterodyne the channel-2 picture carrier at 55.25 Mc into the middle of channel 4 at 69.25 Mc so that a "lacy" mixture of the two pictures is in evidence on channel 4.

The effects of heterodyning, rectification, if interference, etc., may be encountered individually or in combinations, but all are evidence that the TV receiver has inadequate low-frequency rejection. Devices to improve rejection may be installed at the antenna terminals of the television receiver, and one of the simplest of these devices is a pair of tuned traps.

Traps are effective only if the amateur transmitter is operated in a relatively narrow range of frequencies within one amateur band. When the amateur transmitter is operated over a considerable range of frequencies, several pairs of traps can be installed, but problems of matching the television antenna to the receiver are encountered. It is sometimes difficult to get multiple traps to work without causing signal attenuation in several television channels.

Because very few amateurs operate by preference on only one frequency, and because all amateurs are licensed to operate in a number of bands, six of which occur between the frequencies 1.75 and 30 Mc, tuned traps are usually inadequate, and a more efficient device, the high-pass filter, is required for the protection of a receiver located in the vicinity of an amateur transmitter.

Filter Requirements

A high-pass filter for a television receiver has two primary requirements. First, it should reject all signals below the lowest local television frequency. Second, it should function, at television frequencies, as a transmission line having a characteristic resistance equal to that of the television antenna feeder. A theoretically perfect high-pass filter would be capable of fulfilling these requirements; however, in actual practice, compromises must be made in "rejectability" to permit reasonable performance in the TV pass-bands.

For instance, if an attempt were made to design a high-pass filter that would reject all signals below 54 Mc and pass all signals above 55 Mc, the Q of the circuits required would be so high that it would be impossible to construct the device from available components. Even with the best coils and capacitors, the nearest peak-attenuation frequency can be set no nearer than five per cent of the cutoff frequency. Spurious responses that occur in the vicinity of the cutoff frequency of such a filter would also cause difficulties between 50 and 60 Mc. Therefore, rejection of signals from the 6-meter amateur band, especially in a location where channel 2 is assigned, is impractical with a high-pass filter. If a 6-meter signal is to be rejected, the installation of a separate set of tuned traps is the easiest solution to the problem.

For rejecting signals from all of the amateur bands below 30 Mc, however, a high-pass filter is the most practical device that can be installed. With a 25-Mc separation between the television portions of the spectrum and the 10-meter amateur band, there is plenty of room to juggle cutoff frequencies and peak-attenuation frequencies so that optimum conditions can be met for rejecting unwanted signals and accepting all television signals from channel 2 through channel 13.

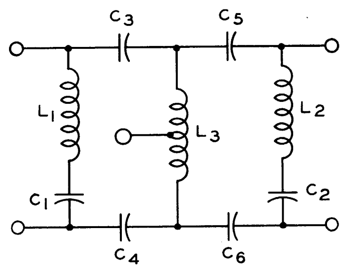

Fig 2. Two-section, series-derived, high-pass filter for a 300-ohm line (Cutoff: approx. 36 Mc).

C_1, C_2 15$\mu\mu$f, mica capacitor, $\pm$ 10% tolerance.

C_3, C_4, C_5, C_6 20$\mu\mu$f, mica capacitor $\pm$ 10% tolerance.

L_1, L_2 2.0μh, 24 turns of #28 DCC wire, coil length 5/8" on 1/4" diam. form. Correct inductance* can be obtained by adjusting the turns to resonate with the associated 15-$\mu\mu$f capacitor at 29 Mc, before setting turns with wax or coil dope.

L_3 0.66 μh, 13 turns of #28 DCC wire, coil length 5/8" on a 1/4" diam. form, center tapped. Correct inductance* can be obtained by adjusting turns to resonate at 19.8 Mc with an auxiliary 100-$\mu\mu$f capacitor.

**Note: If measuring equipment or a grid-dip meter is available, inductances and resonant sections can be adjusted close to specified values. If measuring equipment is not available, however, the coil specifications should be followed closely and a reasonably good filter can be built.*

Constructional Details

The circuit and constructional data are given in *Fig.* 2 for a simple two section, high-pass filter that will work well on most television receivers that are 150 feet or more from an amateur transmitter. For receivers that are closer than 150 feet, or that require more than average filtering, a more elaborate filter may be required. A four-section, high-pass filter that has worked successfully in a number of difficult situations is shown in

C_1, C_2, C_7, C_8 50$\mu\mu$f, Cornell-Dubilier Type 5W capacitors, $\pm$ 5% tolerance.

C_3, C_4 20$\mu\mu$f, Cornell-Dubilier Type 5W capacitors, $\pm$ 10% tolerance.

C_5, C_6, C_9, C_{10} 15$\mu\mu$f, Cornell-Dubilier Type 5W capacitors, $\pm$ 10% tolerance.

L_1, L_2, L_7, L_8 0.62 μh, 10 turns, close spaced, of #28 DCC wire, wound on the associated 50-$\mu\mu$f capacitor. (Type 5W cases are approx. 3/16″x7/16″x11/16″.) The resonant frequency of each of these four LC units should be 29 Mc.

L_3, L_4 1.6 μh, 19 turns of #28 DCC wire on the associated 20-$\mu\mu$f capacitor. Adjust resonant frequency* to 27 Mc.

L_5, L_6 8.0 μh, 23 turns of #28 DCC wire on a ¾″ diam. form. Adjust the resonant frequency of each coil with its associated 15-$\mu\mu$f shunt capacitor to 14.2 Mc*.

L_A 1.05 μh, 16 turns #28 DCC wire, coil length ½″ on a ¼″ diam. form. Correct inductance* may be obtained by adjusting turns to resonate at 15.6 Mc with an auxiliary 100-$\mu\mu$f capacitor.

*For resonance specification requirements, see note under Fig. 2.

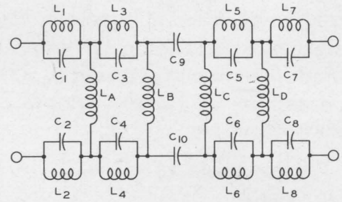

Fig. 3. Four-section, shunt-derived, high-pass filter for a 300-ohm line (Cutoff: 36.25 Mc).

L_B 0.79 μh, 13 turns of #28 DCC wire, coil length ⅝″ on a ¼″ diam. form. Adjust resonant frequency, using an auxiliary 100-$\mu\mu$f capacitor, to 18.3 Mc*.

L_C 0.67μh, 12 turns #28 DCC, coil length ½″ on ¼″ diam. form. Adjust resonant frequency, using auxiliary 100-$\mu\mu$f capacitor, to 19.2 Mc*.

L_D 0.86μh, 16 turns #28 DCC, coil length ¾″ on a ¼″ diam. form. Adjust resonant frequency, using a 100-$\mu\mu$f auxiliary capacitor, to 17.1 Mc*.

Fig. 3. Either of these filters can be built to exact specification with tools and equipment that are at the amateur's disposal. Reasonably good results may be obtained even if each resonant circuit is *not* set to the design frequency, providing the coils are wound as specified. The filters shown are good, practical devices and a "cook-book" method of constructing them may be all that is required to eliminate specific interference conditions. The two-section filter is shown in *Fig.* 1, and the four-section filter is shown in *Fig.* 4. Note how the components are arranged to minimize coupling between coils.

In order to understand the operation of these filters and the simplified design information on the construction of high-pass filters capable of satisfying any requirement, a review of the basic principles of high-pass filter design is of considerable value.

Design Considerations

The following principles are involved in the selection of design parameters for high-pass filters:

1. The cutoff frequency of the filter should be as far as is practical from the pass-band frequencies.

2. The end sections of the filter should match the line. This match is obtained by utilizing the characteristic resistence of the line in the calculations, and by assuming a peak-attenuation frequency of 80 per cent of the design cutoff frequency.

3. The design cutoff frequency, once selected, should be used in the calculations for all sections of the filter.

4. The peak-attenuation frequencies of the intermediate sections should be selected to produce the greatest rejection for particular signals causing the most interference.

With these four principles in mind, let us select the design parameters. The cutoff frequency (f_{co}) will fall between 30 and 55 Mc, preferably nearer 30 than 55. The center of amateur activity in the 30-Mc region is 29 Mc; consequently the maximum attenuation of the end sections is set most advantageously at 29 Mc. If the peak-attenuation frequency, 29 Mc, is to be 80 per cent of the

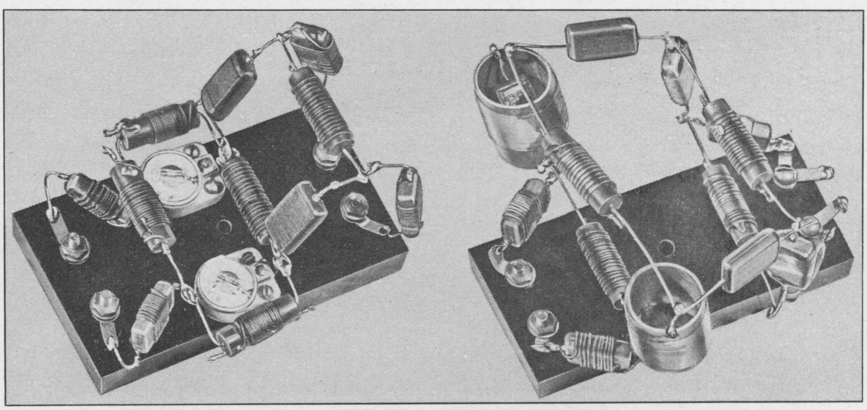

Fig. 4 On the left is shown a three-section, shunt-derived filter. The ceramic trimmers permit adjustment of the 27-Mc intermediate section after the filter has been installed in the TV set. The filter on the right is also a shunt-derived type, except that it has four sections. (Note that some of the coils are wound directly on the mica capacitors).

cutoff frequency, then f_{co} should be 36.25 Mc. Because most television sets use 300-ohm Twin Lead for antenna feeders, 300 ohms will be used for "R" in the sample calculations that follow.

Intermediate Sections

The intermediate sections can provide additional attenuation for 10- or 11-meter signals, and they can also be designed to reject signals from the lower frequency amateur bands. With one intermediate section set for 27 Mc, one for 14.2 Mc, and a third section designed to build up good rejection characteristics in the 1.75, 3.5, and 7 Mc bands, protection against signals from the most populous amateur bands can be obtained. The third intermediate section, the one that rejects the low-frequency amateur signals, is designed by utilizing "0 Mc" as the peak-attenuation frequency in the calculations.

The design parameters for the filter now can be listed in a table to assist in visualizing the arrangement. As a matter of fact, all of the important factors involved in the design of each section can be listed in tabular form. The first three lines of *Table I* show the items discussed thus far. These basic items must be used to determine the factors m and K which match the filter sections to each other and to the line.

Matching Factors

First of all, m is determined by the relation:

$$m = \sqrt{1 - \left(\frac{f_p}{f_{co}}\right)^2}$$

To save time, a curve (*Fig.* 5) has been

Table I — Filter Design Factors

	End Sections	Intermediate Sections			Units
Cutoff Freq. (f_{co})	36.25	36.25	36.25	36.25	Mc
Peak-Attenuation Freq. (f_p)	29	27	0	14.2	Mc
Characteristic Res. (R)	300	300	300	300	ohms
f_p/f_{co}	—	0.745	0	0.392	—
m (from *Fig.* 5)	—	0.67	1	0.92	—
K (from *Fig.* 6)	—	0.205	0	0.041	—
C_1 Shunt-derived filter, *Fig.* 8	48.8	22	14.7	15.9	$\mu\mu$f
L_1 " " " " "	0.62	1.6	open circuit	8.0	μh
L_2 " " " " "	2.2	2.0	1.3	1.4	μh
C_1 Series-derived filter, *Fig.* 7	13.7	34.8	short circuit	176	$\mu\mu$f
C_2 " " " " "	48.8	43.8	29.3	31.8	$\mu\mu$f
L_1 " " " " "	2.2	1.0	0.66	0.72	μh

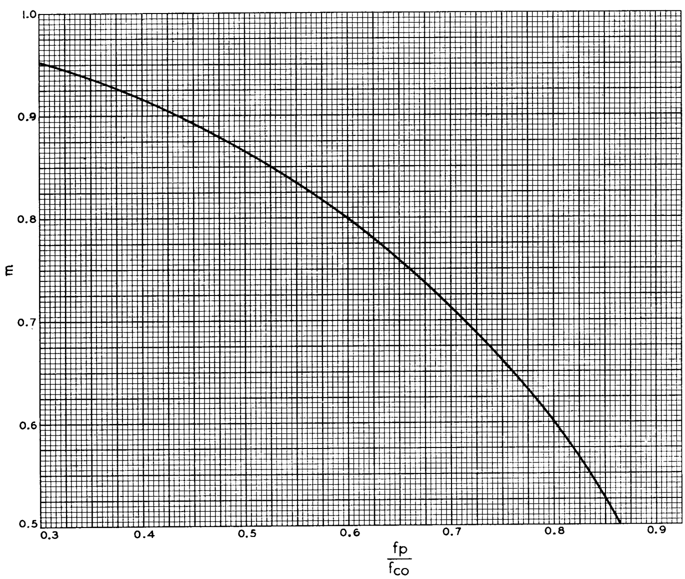

Fig. 5. The matching factor "m" for a high-pass filter section is obtained as follows: Divide the peak-attenuation frequency, f_p, of the section by the cutoff frequency, f_{co}. This quotient is then utilized to locate the value of "m" on this curve.

plotted which performs this operation. Simply read "m" opposite the value of f_p/f_{co} on the curve.

After "m" has been found, "K" can be calculated from:

$$K = \frac{1 - m^2}{4m}.$$

Time can also be saved by taking the value of "m" previously determined, and using *Fig.* 6 to determine K.

When the matching factors, m and K, have been determined, all the items that are necessary for calculating inductance and capacitance values for any filter section are available. All that remains to be done is to take the numerical values of the items determined above, insert them in the appropriate formulas (given in *Figs.* 7 and 8), and perform operations of simple multiplication and division. The results will be values of capacitance and inductance for all components in each filter section.

Formulas for High-Pass Filters

The formulas used in these computations have been simplified from the equations in T. E. Shea's text book, "Transmission Networks and Wave Filters." All of the elements of the original equations have been retained in the simplified formulas presented here, so that a correct match to the television set, to the TV feeder, and between filter sections is maintained.

The circuits and the formulas for designing series-derived, m-type filters are given in *Fig.* 7, and the formulas for shunt-derived, m-type filters are given in *Fig.* 8. A high-pass filter composed of series-derived sections requires fewer coils than a comparable filter composed of shunt-derived sections. To avoid complications, do not use both shunt-derived and series-derived sections in the same filter.

The amount of filtering required in a given installation determines the type of filter to be used and also the number of sections required. In outlying districts, a more effective high-pass filter may be required than would be needed for receivers nearer the TV station. Generally, receivers that are 150 feet or more away from the amateur transmitter can obtain sufficient rejection from a series-derived, two-section filter. For distances between 100 and 150 feet, two to four sections (series-derived) may be required. From experience with high-pass filters, at distances of less than 100 feet and with a transmitter running at 300-watts input, it has been found that three- or four-section shunt-derived filters are the most successful.

Perhaps, with shielding between sections and with the entire filter shielded, fewer sections would be required in the more elaborate units; however, it requires less time to build unshielded multiple-section filters than it does to build simple filters with shielding.

Component values for the two types of filters are listed in *Table I.* These values have been determined from the design formulas given in *Figs.* 7 and 8. Filters composed of one, two, or several sections can be designed from the data in *Table I,* and, in most cases, the only work required to design a good high-pass filter will be the selection of the appropriate component values

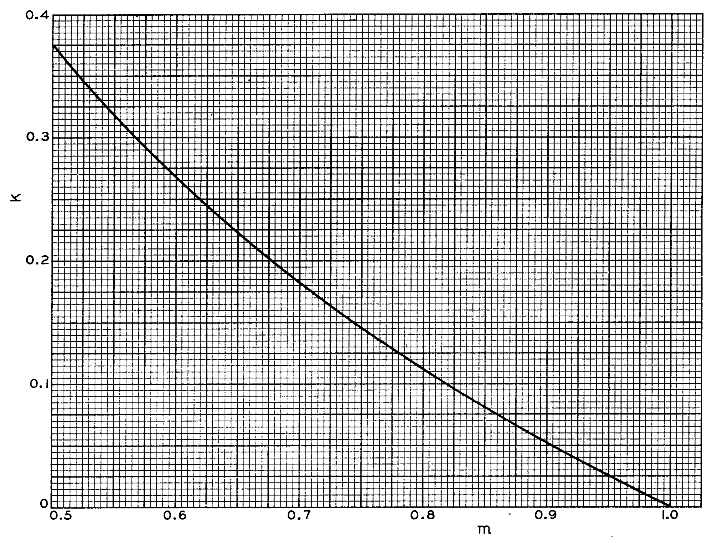

Fig. 6. After "m" is determined for a specific filter section, the corresponding value of "K" is obtained from this curve.

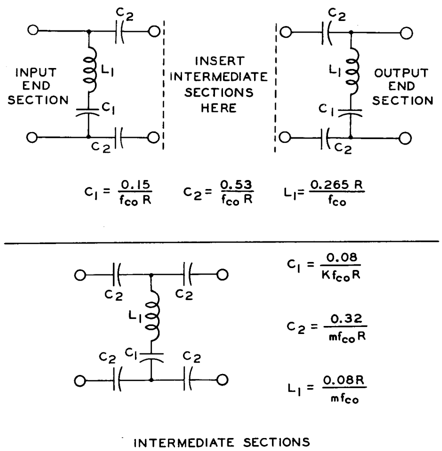

Fig. 7. Circuits and design formulas for series-derived, m-type, high-pass filters. The end sections shown are actually half-sections. They match the line of characteristic resistance, "R", and have maximum attenuation at 80% of the cutoff frequency, f_{co}. The intermediate sections require factors "m" and "K" from Figs. 5 and 6. Units are: C, in farads; L, in henries; frequency, in cps; and R, in ohms.

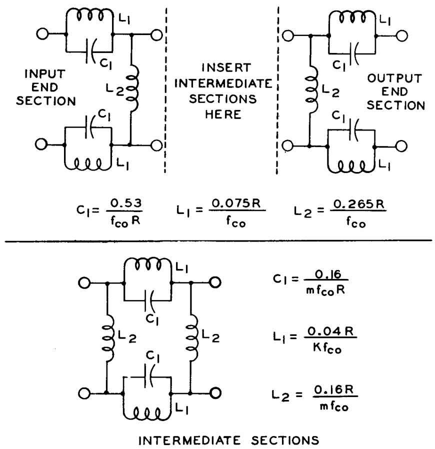

Fig. 8. Circuits and design formulas for shunt-derived, m-type, high-pass filters. The units and constants are described in the caption for Fig. 7. Shunt-derived filters have proved effective on TV receivers using 300-ohm feeders.

from the table. The set of sample calculations which follows may serve as a guide since occasionally a filter may be required for a television receiver operating from a 72-ohm coax, or perhaps a cutoff frequency other than 36.25 Mc may be desired. In such cases, the new values of R and f_{co} should be used with the proper formulas.

Sample Calculations

The following calculations are for a 300-ohm filter composed of shunt-derived, m-type sections:

End Sections (see *Fig.* 8)

$R = 300$, $f_{co} = 36.25$ Mc

$$C_1 = \frac{0.53}{f_{co}R} = \frac{0.53}{36.25(10^6)(300)}$$
$$= 48.8 \times 10^{-12} = 48.8\ \mu\mu f$$

$$L_1 = \frac{0.075\ R}{f_{co}} = \frac{0.075(300)}{36.25(10^6)}$$
$$= 0.62 \times 10^{-6} = 0.62\ \mu h$$

$$L_2 = \frac{0.265\ R}{f_{co}} = \frac{0.265(300)}{36.25(10^6)}$$
$$= 2.2 \times 10^{-6} = 2.2\ \mu h$$

Intermediate Section (*Fig.* 8)

$R = 300$, $f_{co} = 36.25$ Mc, $f_p = 27$ Mc, where

$$\frac{f_p}{f_{co}} = \frac{27}{36.25} = 0.745, m = 0.67 \text{ from } Fig.\ 5.$$

Since $m = 0.67$, $K = 0.205$ from *Fig.* 6.

$$C_1 = \frac{0.16}{mf_{co}\ R} = \frac{0.16}{0.67(36.25)(10^6)(300)}$$
$$= 22 \times 10^{-12} = 22\ \mu\mu f$$

$$L_1 = \frac{0.04\ R}{Kf_{co}} = \frac{0.04(300)}{0.21(36.25)(10^6)}$$
$$= 1.57 \times 10^{-6} = 1.6\ \mu h$$

$$L_2 = \frac{0.16\ R}{mf_{co}} = \frac{0.16(300)}{0.67(36.25)(10^6)}$$
$$= 1.98 \times 10^{-6} = 2.0\ \mu h$$

Intermediate Section (*Fig.* 8)

$R = 300$, $f_{co} = 36.25$ Mc, $f_p = 0$ Mc*, where

$$\frac{f_p}{f_{co}} = \frac{0}{36.25} = 0, m = 1, \text{ and } K = 0$$

$$C_1 = \frac{0.16}{mf_{co}\ R} = \frac{0.16}{1(36.25)(10^6)(300)}$$
$$= 14.7 \times 10^{-12} = 14.7\ \mu\mu f$$

$$L_1 = \frac{0.04\ R}{Kf_{co}} = \frac{0.04\ R}{0\ f_{co}} = \infty$$

$\therefore L_1$ is equivalent to an open circuit.

$$L_2 = \frac{0.16\ R}{mf_{co}} = \frac{0.16(300)}{1(36.25)(10^6)}$$
$$= 1.32 \times 10^{-6} = 1.3\ \mu h$$

**This section builds up the attenuation capabilities of the filter at low frequencies. It aids in the rejection of the 1.75, 3.5 and 7-Mc amateur bands.*

An intermediate section for $f_p = 14.2$ Mc could be calculated in the same manner as for the 27-Mc section. Other sections could be used instead of those for 14 and 27 Mc if the interfering signal occurs at some other frequency.

C_1, C_2, C_7, C_8 50-$\mu\mu$f, Cornell-Dubilier Type 5W capacitors; $\pm$5% tolerance.
C_5, C_6 15 $\mu\mu$f, Cornell-Dubilier Type 5W capacitors, $\pm$10% tolerance.
C_3, C_4, 4-30 $\mu\mu$f, variable ceramic capacitor, Erie TS2A-N500.
L_1, L_2, L_7, L_8 0.62 μh, 10 turns #28 DCC wire close spaced, wound on the associated 50-$\mu\mu$f capacitor. Adjust inductance to produce a resonant frequency of 29 Mc* for each LC unit.
L_5, L_6 8.0 μh, 40 turns of #34 enamel wire close wound on associated 15-$\mu\mu$f capacitor. Adjust inductance to produce a resonant frequency of 14.2 Mc*.
L_3, L_4 1.6 μh, 17 turns of #28 DCC wire, coil length 3/8" on 1/4" diam. form. When the 4-30 $\mu\mu$f shunt capacitor is set at maximum capacitance, the resonant frequency of the combination should be 23 Mc.
L_A 1.05 μh, 16 turns #28 DCC, coil length 1/2" on 1/4" diam. form. Correct inductance* may be obtained by adjusting turns to resonate at 15.6 Mc using an auxiliary 100-$\mu\mu$f capacitor.
L_B 0.83 μh, 17 turns #28 DCC, coil length 7/8" on 1/4" diam. form. Correct inductance* may be obtained by adjusting turns to resonate at 17.4 Mc using an auxiliary 100-$\mu\mu$f capacitor.
L_C 0.86μh, 16 turns #28 DCC, coil length 3/4" on 1/4" diam. form. Adjust to resonate at 17.1 Mc. using an auxiliary 100-$\mu\mu$f capacitor.

*For resonace specification requirements, see note under Fig. 2.

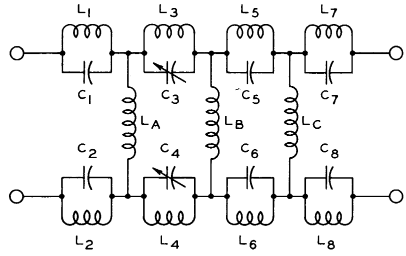

Fig. 10 Circuit diagram of a three-section, shunt-derived filter for 300-ohm TV feeder. The usable tuning range of the adjustable section is 25 to 30 Mc.

When the values for all of the components in the filters have been determined, the circuit may be diagrammed as shown in *Fig. 9*. The filter could actually be wired as indicated, but the circuit can be simplified by combining the inductance values which are in parallel. The basic operation is the same as that for determining the combined value of resistors in parallel. The combined value of inductances L_x and L_y in parallel is equal to

$$\frac{1}{L_x}+\frac{1}{L_y}=\frac{1}{L_{total}}$$

The four pairs of adjacent inductors in *Fig. 9* are combined to complete the sample calculations:

Coil A: $$\frac{1}{2.2}+\frac{1}{2.0}=\frac{1}{L_A}=\frac{2.2+2.0}{(2.2)(2.0)}$$
$$\therefore L_A = 1.05\ \mu h$$

Coil B: $$\frac{1}{2.0}+\frac{1}{1.3}=\frac{1}{L_B}=\frac{2.0+1.3}{(2.0)(1.3)}$$
$$\therefore L_B = 0.79\ \mu h$$

Coil C: $$\frac{1}{1.3}+\frac{1}{1.4}=\frac{1}{L_C}=\frac{1.3+1.4}{(1.3)(1.4)}$$
$$\therefore L_C = 0.67\ \mu h$$

Coil D: $$\frac{1}{1.4}+\frac{1}{2.2}=\frac{1}{L_D}=\frac{1.4+2.2}{(1.4)(2.2)}$$
$$\therefore L_D = 0.86\ \mu h$$

Mechanical Considerations

The final circuit for the four-section, shunt-derived filter is the one shown in *Fig.* 3. The four section-coupling coils calculated above were made by winding No. 28 DCC wire on 1/4-inch bakelite rods. The other coils were made by winding insulated wire around the capacitors as shown in the photograph of the completed filter. A higher Q is obtainable, however, if the coils are wound separately. As many of the coils as possible should be mounted at right angles to each other, and a reasonable physical separation should be kept between components to minimize coupling. The size of this filter is 3½" x 2½" x 2½".

It is sometimes helpful to have one section in a high-pass filter that can be tuned after it has been installed so that adjustment for maximum rejection of a particular interfering signal can be made. A three-section filter having a pair of tunable components for adjusting the maximum rejection point between 25 and 30 Mc is shown in *Fig.* 4. This

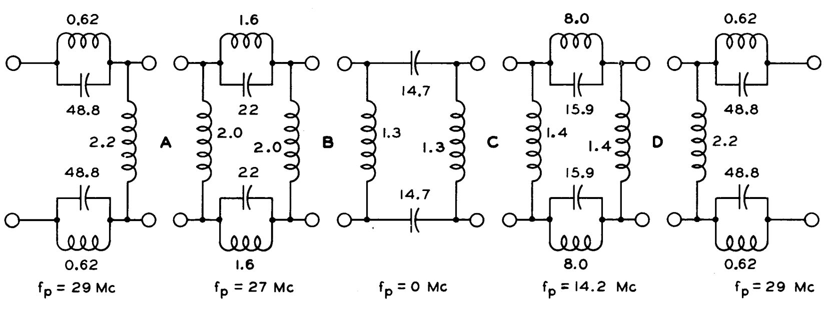

Fig. 9. The four sections of the shunt-derived filter should be drawn in this manner before the adjacent inductances are combined. After the inductances are combined, the circuit is identical to that of the filter given in Fig. 3.

filter has shunt-derived, m-type sections; its circuit is shown in *Fig.* 10.

When a tuned section is incorporated in a series-derived filter, the tuned resonant circuit is located in a shunt arm.

Series-Derived Filters

The arithmetic required for calculating component values for series-derived filters is similar to that shown in the shunt-derived example, the only difference being in the calculations needed for combining series capacitors. The formula

$$\frac{1}{C_x}+\frac{1}{C_y}=\frac{1}{C_{total}}$$

should be used if a minimum number of capacitors is to be employed.

The circuit for the two-section, series-derived, high-pass filter, *Fig.* 2, shows a tap at the center of the shunt coil. This tap is available for grounding the filter to the TV receiver chassis. Improved rejection has been obtained in some instances when a very short ground lead is run from this tap to the chassis. In many other installations, however, such a ground connection had no effect on the attenuation characteristic of the filter.

Filters for TV Coax

Thus far, only filters for balanced lines have been discussed. Unbalanced feeders of the coax type theoretically should require an unbalanced filter, a configuration in which all of the series-reactive components are placed in the circuit of the center conductor. In some cases, in particular those in which the signal to be rejected is reasonably weak, the unbalanced type of filter is adequate. Sometimes, however, a strong amateur signal also produces a standing wave on the outside of the TV coax, and the rf field that is present, in the region where the coax is connected to the receiver, couples energy to incompletely shielded components of the receiver. When this condition occurs, the outer conductor of the coax must be considered as a second wire, and it must therefore also be isolated from the receiver chassis by filter components. Such a filter would be a normal balanced line configuration, calculated for 72 ohms. A sketch of such an installation is shown in *Fig.* 11.

Where a TV coax shield is *not* coupling energy to the set components, an unbalanced-line filter is satisfactory. A small shield-can with coax fittings makes a good housing for an unbalanced line filter. The unit should be fastened to the TV chassis at a point where the "front-end" connection can be kept as short as possible.

Converting Balanced to Unbalanced Structures

Designing unbalanced filters from the formulas given in *Figs.* 7 and 8 is a simple matter. For 72-ohm coax, use 72 ohms for the value of "R" in the formulas and determine the values of all components, as in a balanced filter. The components that are connected across the transmission line in each section remain unchanged; the components in series with the transmission lines, however, must be lumped and placed in only one of the lines. The other line is a common ground to all sections of the filter. *Fig.* 12 illustrates the conversion as applied to individual filter sections.

The conversion of a balanced filter to an unbalanced filter can also take place after the sections of a balanced filter have been combined. An example of this method of conversion is shown in *Fig.* 13. The component values given in this figure are practical,

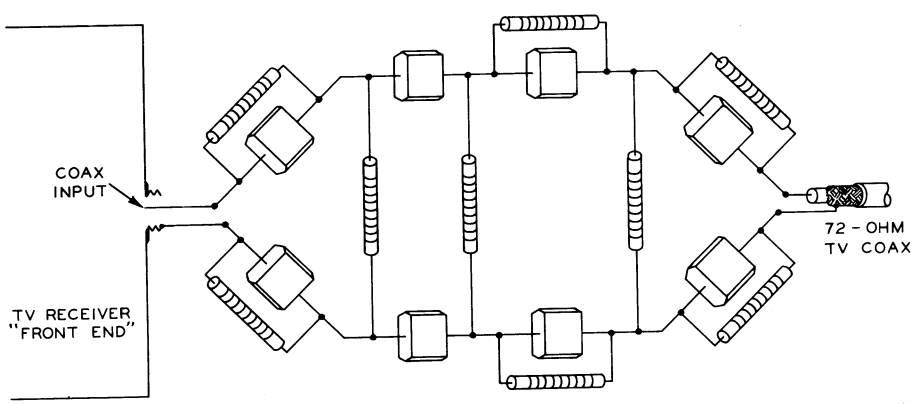

Fig. 11. Sketch showing how the inside and outside conductors of a coaxial transmission line are connected to a balanced 72-ohm, high-pass filter. This arrangement may be found necessary if an unbalanced-line filter is inadequate.

by other components in the filter section. The theoretical attenuation of each filter section at any given frequency can be calculated. Curves representing the attenuation characteristics of the individual sections listed in *Table I* are shown in *Fig.* 15.

When the attenuation is designated in decibels, it is easy to determine the combined effect of two or more sections of a filter because the attenuation values, at a given frequency can be added numerically. The sum of the values for all sections is the attenuation, at the given frequency, of the entire filter. The theoretical attenuation curves for three specific filters are shown in *Fig.* 16. When the attenuation in a given filter is estimated, keep in mind that for each 6 db of attenuation the voltage is cut in half. For instance, 24-db attenuation of a 1-volt signal would be equivalent to four progressive reductions of 50 per cent (0.5, 0.25, 0.125, and 0.0625), producing an output of 0.0625 volt.

If a particular receiver evidences interference when a 1-volt signal is introduced at the input to the tuner, some attenuation of that signal is required. Perhaps a filter capable of an attenuation of 24 db is adequate. Then, with such a filter, interference rejection would be satisfactory unless a 16-volt signal happened to be introduced. Sixteen volts is 24 db above one volt, so a 48-db filter would be required to provide adequate rejection of the stronger signal.

Sixteen volts may seem like a lot of rf to be available on a TV antenna, but voltages of this order of magnitude are not unusual when an amateur transmitter and a television receiver are within 15 or 20 feet of each other. As a matter of fact, a number of cases have been reported in which a neon bulb could be lighted at the TV receiver terminals when the amateur transmitter was on the air. Neon bulbs do not glow unless the potential applied is approximately 50 volts or higher.

Because television-antenna transmission lines do not match the antenna and the receiver at low frequencies, standing waves from the amateur signal are present on the line. A voltage-maximum point occasionally occurs at the receiver terminals, and when this condition exists, changing the length of the TV feeder may shift the location of the voltage maximum and reduce the rf at the receiver terminals. Adjustments of this type are helpful in minimizing the burden placed on a high-pass filter.

Other Paths for Interfering Signals

The installation of a booster also changes the effective length of a transmission line. Furthermore, after a booster has been installed, it may be found that there is an

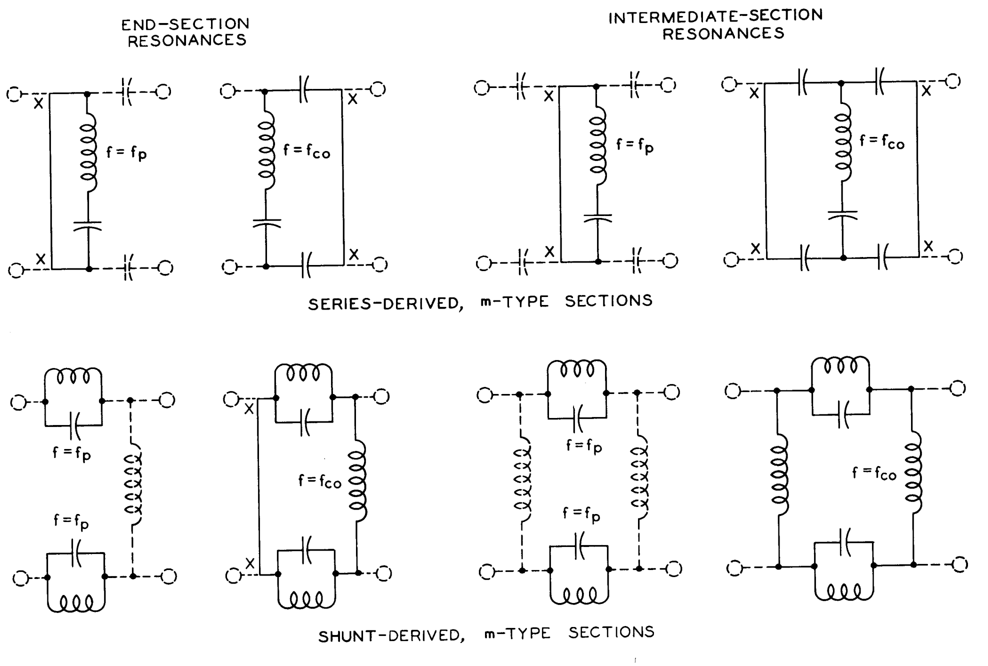

Fig. 14. The resonant circuits designated by solid lines are the combinations utilized to check the filter design calculations. Although not actually connected in a filter, lines x-x are shown to complete the resonant circuit when it is checked mathematically.

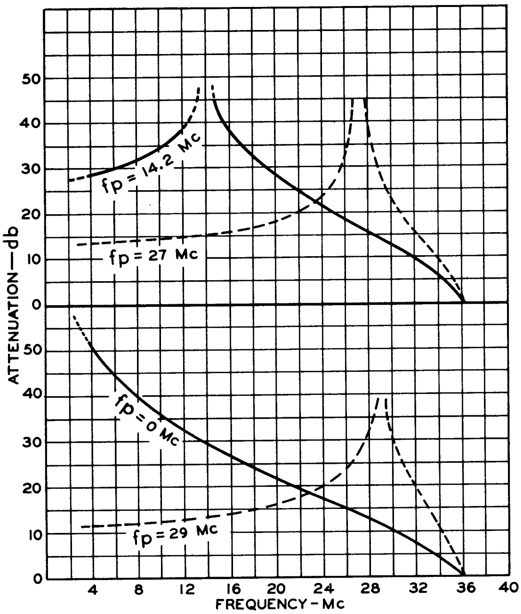

Fig. 15. These curves show the theoretical attenuation for individual sections of high-pass filters. The combined effect of the two end-sections is given in the 29-Mc curve. The other three curves are for intermediate sections. All of these sections were designed for a cutoff frequency of 36.25 Mc. There should be no attenuation above that frequency.

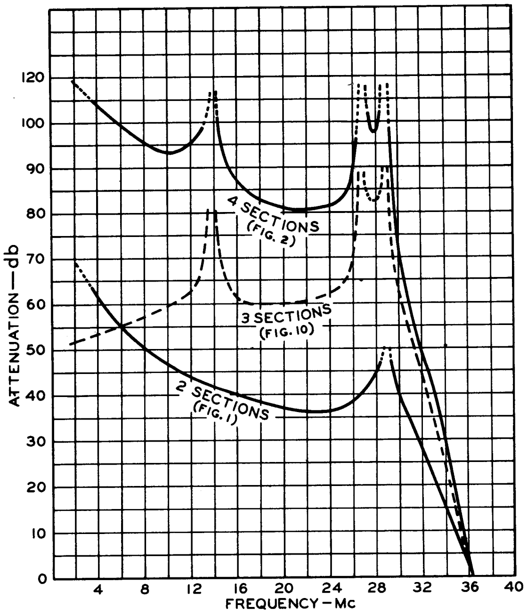

Fig. 16. Theoretical attenuation of several of the filters discussed in this article. In actual practice, these filters have been effective in rejecting amateur signals, and there has been no evidence of attenuation in the TV pass bands.

increase in interference due to the addition of one or more paths along which the amateur signal can enter the television receiver. Preventing an amateur fundamental from entering a booster is just as important as preventing the signal from entering a TV receiver, so a high-pass filter at the booster input is required. Sometimes a second high-pass filter is required between the booster and the receiver because the transmission line between the two units can pick up a strong amateur signal. The power-supply cord to the booster may also be involved in the transfer of an amateur fundamental to the TV receiver.

Supply-Line Filters

In some installations, the line cord to the TV receiver has been found to be a path along which the amateur signal enters the receiver. The amateur signal can get into the power line either by being fed directly into the ac line at the transmitter, if the rf filters in the power supply are inadequate, or by being picked up by the house wiring at the TV receiver location. The house wiring, including BX cable, may be a very effective receiving antenna.

Water, gas, and steam pipes are also capable of acting like receiving antennas. A "ground" wire connected from a TV receiver to a radiator may couple an amateur signal to the exposed components of a TV chassis. Direct pick-up by long leads in phonograph-radio TV consoles have also been found capable of introducing unwanted signals.

All long leads—line cords, speaker cables, etc. are capable of introducing a strong amateur signal to the vulnerable sections of a television receiver. RF chokes, placed in series with the leads, help in rejecting the undesired signals. A bypass capacitor connected at the point where the lead enters the chassis adds to the effectiveness of the choke in eliminating the interfering signal.

Conclusion

There are many variables involved in reducing interference in a television receiver. Each installation where interference is encountered may be slightly different from all the others. Fortunately, however, high-pass filters *will* solve almost all of the amateur interference problems attributable to receiver difficulties, and intelligent application of these devices should reduce to a minimum the number of unhappy situations that exist in the radio amateur's neighborhood.

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300-Watt Modulator with 811-A Push-Pull Output

By

George E. Jones, Jr., W2CBL*

HERE is a speech amplifier and modulator capable of delivering 300 watts of audio power through a multi-match modulation transformer into a wide range of class C loads. This unit is especially suitable for use with a transmitter such as the 500-watt rig which was designed by the author and described in a previous issue of HAM TIPS.**

The 811-A modulators are operated at zero bias and a plate voltage of 1250 volts. A 400-volt, 180-milliampere supply for the speech amplifier is included on the modulator chassis.

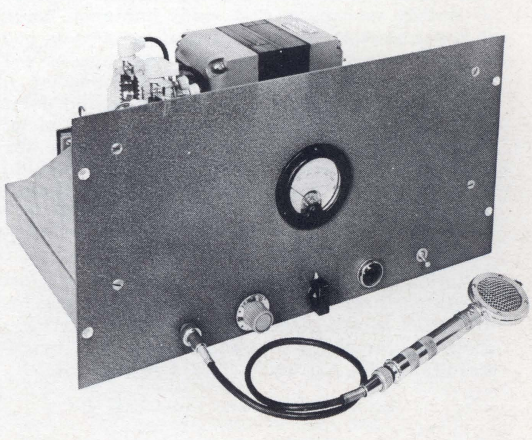
Circuit Considerations

A circuit diagram for the modulator is given in *Fig. 1.* The 6SJ7 amplifier stage is a high-gain stage (gain of approximately 180) designed to operate from the output of a high-impedance crystal or dynamic microphone. The input network (R_1C_1) has been designed to eliminate rf feedback, a difficulty often experienced when high-voltage rf fields are present. This network attenuates any rf voltage picked up in the input circuit before it reaches the grid of the 6SJ7.

One half of the first 6SN7 tube is used as an amplifier directly coupled to the second half of the tube, which is used for phase inversion, to obtain a push-pull signal for the following 6SN7. The cathode and plate resistors, R_{10} and R_{12}, respectively, should be matched resistors. The direct-coupled amplifier and the phase-inverter circuit is an adaptation of the well-known "Williamson Circuit." The second 6SN7 is a push-pull amplifier for driving push-pull, triode-connected, class A 807 drivers. The plate resistors R_{17} and R_{18}, in the push-pull 6SN7 stage, must be matched resistors to insure a balanced signal in the push-pull stages. Resistors having a tolerance of 5 per cent (gold band) are used for R_{10}, R_{12}, R_{17}, and R_{18}. For all other resistors, a tolerance of ± 10 per cent (silver band) is satisfactory.

Construction

The unit is constructed on a conventional 2 by 13 by 17-inch chassis and utilizes a 10½ by 19-inch rack-mounting front panel. Layout of the parts



is shown in the photographs. For operating convenience, all the necessary controls are located on the front panel. From left to right, in the above photograph, are shown the microphone input connector, the gain control R7, the cw-phone control switch SW_2, the power indicating pilot

*RCA Tube Dept., Harrison, N.J.

**May-August, 1948 (Vol. 8, No. 2)

TVI BIBLIOGRAPHY

Although it is generally agreed that TVI is a problem that will ultimately confront every amateur, most of us are inclined to avoid the subject until we are faced with a specific complant. The bibliography of articles on TVI on page 3 has been compiled to assist you in overcoming that apparently formidable obstacle to the continued enjoyment of operating your amateur station.

The listed articles contain many suggestions of value to the amateur who is planning to build a new transmitter. The probability of interference can be reduced appreciably if the transmitter design incorporates the recommended precautions to prevent the generation of spurious radiations. From the practical viewpoint, this approach is logical because it requires less effort than is needed for the application of elaborate corrective measures after the transmitter is built.

light PL_1, and the power-supply on-off switch SW_1. Meter M_1 is mounted in the center of the panel and is wired into the center tap of the transformer which supplies the 811-A filament power. The meter is placed at ground potential and indicates tube current (total grid and plate current) of the modulator tubes. The front panel and all controls are at ground potential for safety reasons.

The chassis layout is shown in *Fig. 2.* The power-supply components, viewed from above, are grouped at the upper left-hand side; the modulation transformer is mounted directly behind this supply. The speech amplifier starts at the upper right-hand side and continues to the rear of the chassis. This layout provides a very short, direct input connection to the speech amplifier, and isolates the high-gain amplifier stages from the power supply and modulator output transformer.

Wiring is simple and the 2-inch-deep chassis, shown in *Fig. 3,* provides easy access for wiring and soldering all components. The layout was chosen to minimize the possibility of oscillation, "motor boating," or hum pick-up; lead dressing and placement of parts are not critical. In order to obtain maximum gain with minimum hum, it is necessary to tie the ac and dc returns to one common ground point in the first stage of the speech amplifier. Microphone cable connector J_1 should be connected to the common ground point instead of being grounded directly to the metal chassis. This jack should be insulated from the chassis, and the input wiring of the 6SJ7 should be kept as short as possible to avoid extraneous pickup.

Adjustment and Operation

Variable resistor R_{29} in the power supply, just ahead of filter capacitor C_{14}, should be set for 400 volts at the output end of the second filter choke L_2. Ample decoupling is provided by capacitors C_4, C_8, C_9, and C_{11}, and resistors R_6, R_9, and R_{13} to minimize interstage coupling which could result in motor boating.

The 807 push-pull, triode-connected class A stage has a potentiometer (R_{20} accessible at the rear of the chassis) in the cathode circuit for balancing the plate currents of the two tubes. This adjustment is made at static (zero signal) conditions, and, once set, need not be changed unless the 807 tubes are changed. Test measurements on the completed speech amplifier show that positive grid current begins to flow in the second 6SN7 and the 807's at the same input-signal level, so the values of biasing resistors for the various stages are nearly optimum. In operation, the 811-A milliammeter will indicate about 125 ma on the peak swings of normal speech when the 1250-volt plate supply is off. When the plate supply is on, this current increases to approximately 450 ma on voice peaks for full output. With a sine-wave signal input, the 811-A's deliver approximately 300 watts into a fixed resistance load before the amplifier is overdriven (as evidenced by flattening of the sine-wave output voltage).

The driver transformer, T_1, is connected to obtain the maximum step-down ratio (primary-to-secondary) to provide for ample drive to the 811-A grids and also good regulation of the grid voltage for the class B stage.

The terminals on the multi-match transformer T_2, in the output, are connected so that the 9200-ohm, plate-to-plate load of the 811-A's is matched to the approximately 4000-ohm load of an 812-A push-pull, class C amplifier.

A suggested connection for the cw-phone control switch SW_2 is shown in *Fig. 1* with dotted-in connections to the class B and class C plate power-supply relays.

The amplifier is stable at full setting of the gain control. The frequency response characteristic of the amplifier and modulator is flat from 100 to 7,000 cps; it drops off only slightly from 7,000 to 10,000 cps.

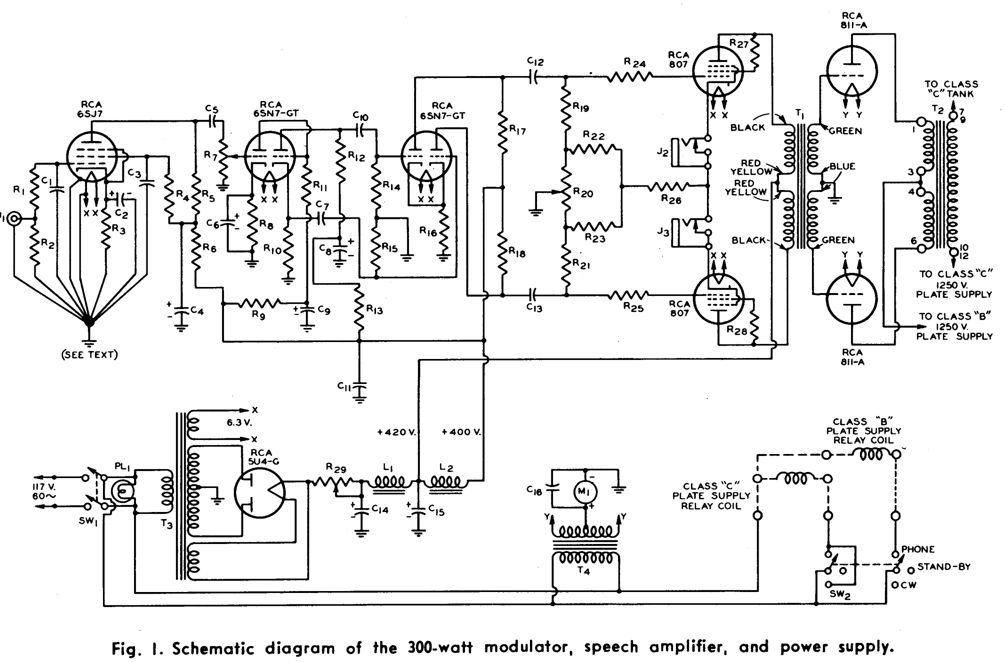


Fig. 1. Schematic diagram of the 300-watt modulator, speech amplifier, and power supply.

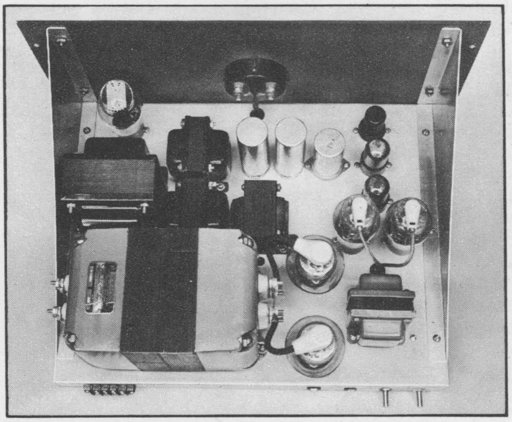


Fig. 2. Top view of the modulator; note that the well-planned layout of the modulator components permits the inclusion of a husky power supply on the same chassis.

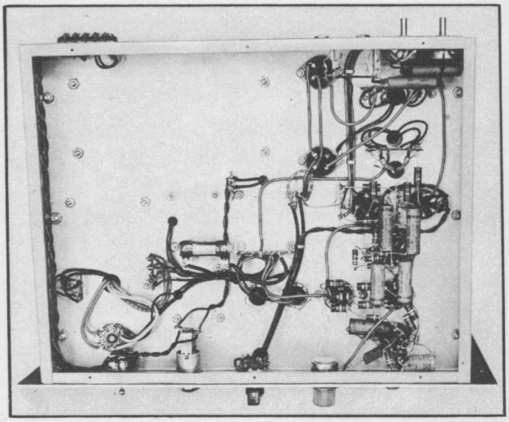


Fig. 3. Bottom view of the modulator; accent on simplicity and accessibility! Excellent performance, and no hum or feedback, without special dressing of leads or shielding!

PARTS LIST

C_1	0.0005 μf, mica, 600 v.
C_2	4 μf, electrolytic, 25 v.
C_3, C_7, C_{10}, C_{12} & C_{13}	0.1 μf, paper, 600 v.
C_4, C_8, C_9 & C_{11}	20 μf, electrolytic, 450 v.
C_5	0.005 μf, mica, 600 v.
C_6	40 μf, electrolytic, 25 v.
C_{14} & C_{15}	16 μf, electrolytic, 600 v.
C_{16}	0.01 μf, mica, 600 v.
J_1	Microphone-cable connector.
J_2 & J_3	Normally closed jack.
L_1 & L_2	Filter choke, 8 henrys at 150 ma, Thordarson T20C54 or equivalent.
M_1	Meter, 0-500 ma, Weston 301 or equivalent.
PL_1	Pilot lamp, 125 v., 3 watts.
R_1	100,000 ohms, ½ watt.
R_2	240,000 ohms, ½ watt.
R_3	2,000 ohms, 1 watt.
R_4	1.5 megohms, 1 watt.
R_5, R_{14}, & R_{15}	470,000 ohms, 1 watt.
R_6, & R_{11}	47,000 ohms, 1 watt.
R_7	Potentiometer, 0.5 megohm, 1 watt.
R_8	470 ohms, 1 watt.
R_9	30,000 ohms, 1 watt.
R_{10} & R_{12}	22,000 ohms, 1 watt (matched).
R_{13}	22,000 ohms, 1 watt.
R_{16}	820 ohms, 1 watt.
R_{17} & R_{18}	47,000 ohms, 1 watt (matched).
R_{19} & R_{21}	100,000 ohms, 1 watt.
R_{20}	Potentiometer, 100 ohms, 2 watts.
R_{22} & R_{23}	100 ohms, 10 watts.
R_{24} & R_{25}	1,000 ohms, 1 watt.
R_{26}	330 ohms, 10 watts.
R_{27} & R_{28}	100 ohms, 2 watts.
R_{29}	Adjustable, 100 ohms, 25 watts.
SW_1	DPST toggle switch.
SW_2	Double-pole triple-throw switch.
T_1	Driver transformer, primary to ½ secondary (5:1), Thordarson 20D82 or equivalent.
T_2	Multi-match modulation transformer, Thordarson 21M64 or equivalent.
T_3	Power transformer, 400-0-400 v, 200 ma; 5 v, 3 amp; 6.3 v, 5 amp, Thordarson TS24R07-U or equivalent.
T_4	Filament Transformer, 6.3 v at 10 amp, Thordarson T21F12 or equivalent.

TVI BIBLIOGRAPHY

A comprehensive listing of articles on TVI and related topics that have appeared since 1946. Although the articles appearing in the non-amateur publications contain only minor references to the amateur and TVI, they have been included to supply the advanced amateur with a complete set of references. A few articles on interference from sources other than amateur transmitters as well as some editorials have been listed. Radio amateur groups will find the editorial articles valuable references for discussions. Note that the articles are listed in chronological order; this has been done to facilitate retrospection, and to permit easy cross reference to TV reception techniques and improvements.

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HAM TIPS

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Volume XI, No. 1 Spring, 1951

Compact 2-Meter Civil-Defense Transmitter Employs RCA Miniatures and Popular 2E26

By

George D. Hanchett, Jr., W2YM*

When the FCC reserved sections of the two-meter and other bands for Civil-Defense operations in the event of war, public-spirited amateurs recognized the need for compact mobile and fixed-station equipment. In order to help fill this need, the transmitter described in this article was designed and constructed. This versatile two-meter transmitter meets the requirements of extreme reliability, minimum stand-by power consumption, ease of adjustment, and portability. It may be operated either from a 117-volt ac line or from a 6-volt storage battery; this transmitter provides an output of approximately 10 watts.

As SHOWN in the schematic diagram on *pg. 4*, a 6AK6 is employed as a crystal oscillator-tripler stage. Starting with an 8-Mc crystal, this stage provides a 24-Mc signal to the second 6AK6 which triples to 72 megacycles. A 5763 miniature beam-power amplifier is used as a doubler and a 2E26 operates as the final amplifier at 144 megacycles. For maximum power efficiency, a 1635 is used as a class B modulator. A 6N7-GT may be employed to obtain the same modulator output, but the 1635 has the advantage of requiring less heater power and a lower zero-signal plate current. The first audio amplifier utilizes one half of

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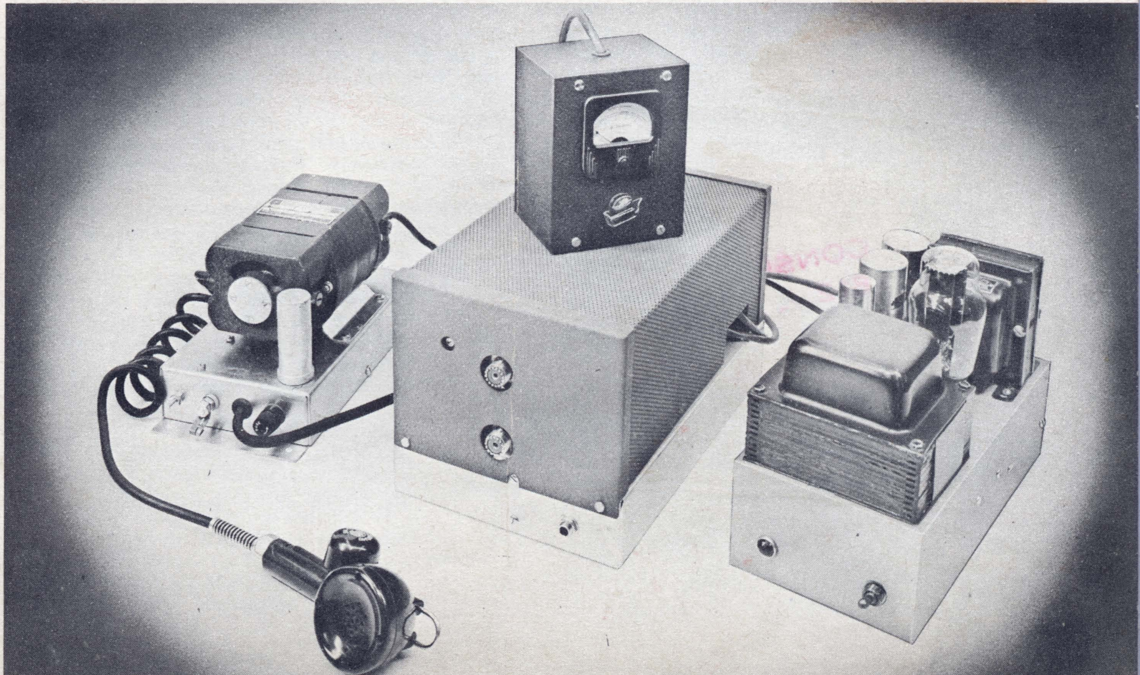
Fig. 1. A compact Civil-Defense transmitter for fixed-station or mobile operation.



a 12AU7 as a grounded-grid stage to obtain a good match to the carbon microphone, and also to provide a convenient source of voltage for the microphone.

Meter Circuit

Metering the grid circuits of the frequency multipliers and the final amplifier, and the plate circuits of both the final amplifier and the class B modulator is accomplished by means of an external test meter. This arrangement permits the use of a single meter for adjusting all of the transmitters in a Civil-Defense network.*

As shown in *Fig. 2,* the test-meter circuit consists of a 0-1 ma meter, a two-section six-position switch, and two resistors. Connection of the test meter to the transmitter is made by means of a cable and plug.

When the meter switch is set to any one of the first three positions shown in *Table I,* the 3,900-ohm multiplier resistor and the milliammeter are connected in series between ground and a point on a voltage divider in the grid circuit. The meter deflection is proportional to the flow of grid current.

In positions 4 and 5 of the meter switch, the meter and the 910-ohm resistor, in series, are connected across a 10-ohm shunt (R_{23} for position 4, or R_{22} for position 5) to indicate the final-amplifier or modulator plate current, respectively. The test meter is connected between ground and a 1N34 rectifier in the antenna-coupling circuit in position 6 of the meter switch.

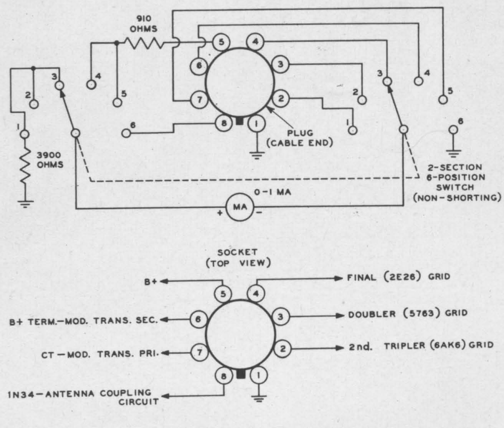


Fig. 2. Test-meter circuit.

Table I — Test-Meter Calibration Data

Switch Position	Indication	Full-scale Deflection
1	2nd tripler (6AK6) grid current	5 ma
2	Doubler (5763) grid current	5 ma
3	Final (2E26) grid current	5 ma
4	Final (2E26) plate current	100 ma
5	Class B mod. plate current	100 ma
6	RF power output	15 watts

Construction

The transmitter is constructed on a 7 by 11 by 2-inch chassis; it is so arranged that the rf section is on one side of the chassis (refer to *Fig. 3*) and the modulator and power plugs on the other side. Separating these two sections, on the underside of the chassis, is a strip of aluminum to which a resistor board is fastened. All of the resistors, with the exception of the 5763 grid resistor, R_{10}, are mounted on this board. Such mechanical support of the resistors provides the necessary ruggedness for mobile operation.

By-passing in the frequency multipliers and the final amplifier is accomplished with single-and dual-section ceramic capacitors. The metering leads are brought to an octal meter jack for connection to the external test meter. Transformer T_1 is a standard RCA TV sound if unit, 206K1, and L_1 is a stagger-tuned video if coil, 202L1.

The arrangement of the components in the output tank circuit is shown in *Fig. 5.* The bracket for this tank circuit is made from a 4 by 5-inch piece of aluminum. The output link coil is connected to a coaxial relay so that in the non-energized position, the antenna will be connected to the associated receiver.

**Each unmetered transmitter may be monitored during transmission by a pair of headphones connected to monitor jack J5 in the antenna-coupling circuit.*

Adjustment

The tuning of the transmitter is a simple process. With only the two 6AK6's in place, connect the transmitter to the 300-volt supply. Connect the test meter to the unit and set the selector switch to the second tripler-grid position. Vary the inductance of L_1 to obtain oscillation, and then adjust the primary and secondary of T_1 for maximum meter deflection. The grid current of the second 6AK6 should be approximately 2 ma.

Insert the 5763 into the transmitter and adjust L_2 to resonance as indicated by maximum 5763 grid current when the test meter is set in position 2. At resonance the grid current of the 5763 should be approximately 1 ma. Adjust-

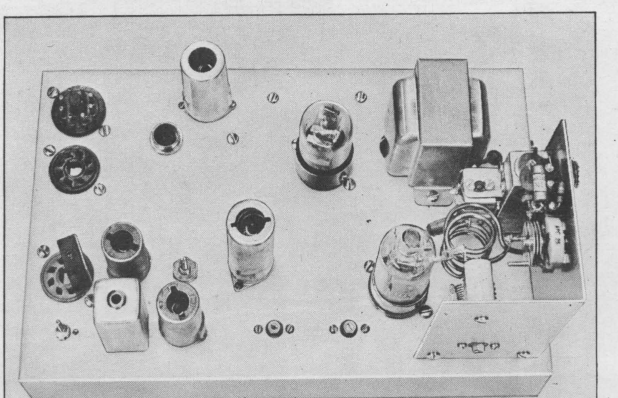


Fig. 3. Top view of the transmitter.

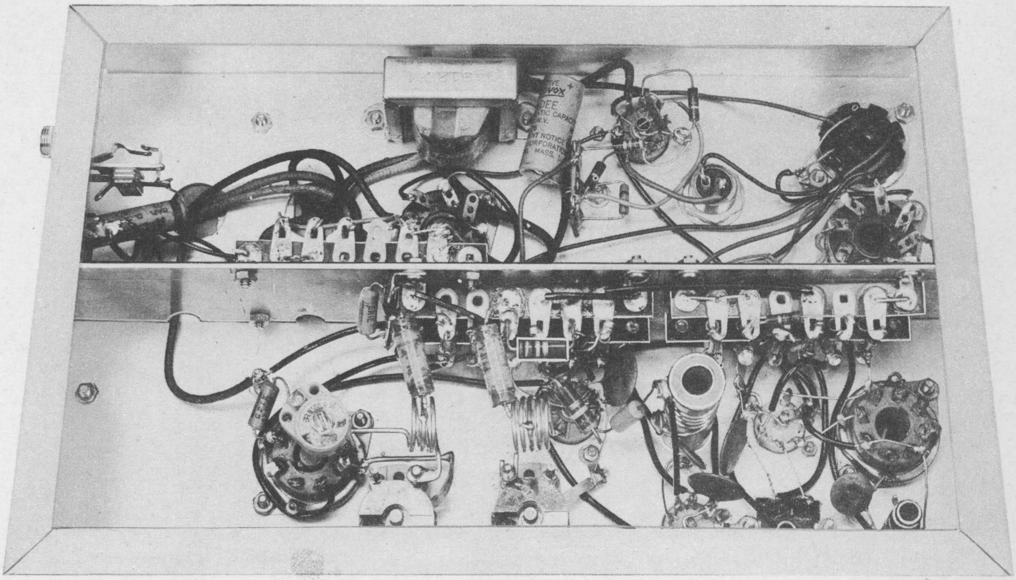


Fig. 4. Bottom view of the transmitter. The resistor board provides the necessary mechanical support for mobile operation.

ment of L_2 should be made as rapidly as possible, so that the 5763 plate circuit (which will probably not be in resonance) does not draw excessive current for a sustained period.

Switch the test meter to the 2E26 grid position (3) and plug in the 2E26. To protect the 2E26 during the initial tune-up, disconnect the series screen resistor, R_{16}, from the plate supply. Then adjust C_{14} and C_{15} for maximum grid current in the 2E26; the 2E26 grid current should be approximately 1.5 to 2.0 ma.

At this point in the initial tuning procedure, the final amplifier should be neutralized as follows: rotate C_{20} through its entire range and observe the downward kick of the test meter (switch set in position 3, the 2E26 grid-current position). Then adjust neutralizing capacitor C_N until the downward deflection of the meter needle is minimized when C_{20} is rotated through its range. Reconnect the screen-grid resistor to the plate supply and set the meter selector switch to the 2E26 plate-current position (4). Capacitor C_{20} should then be adjusted for resonance.

After these adjustments have been made, connect the antenna to the transmitter and set the test meter switch to the output position (6). Capacitor C_{21} should be adjusted for maximum output. When a 52-ohm coax cable is used, a meter reading of approximately 0.4 ma indicates 10 watts of rf power. Finally, readjust L_1, T_1 C_{14}, C_{15}, and C_{20} for maximum power output.

The 1635 class B modulator tube and the 12AU7 speech-amplifier tube should then be plugged in and the microphone connected to the transmitter.

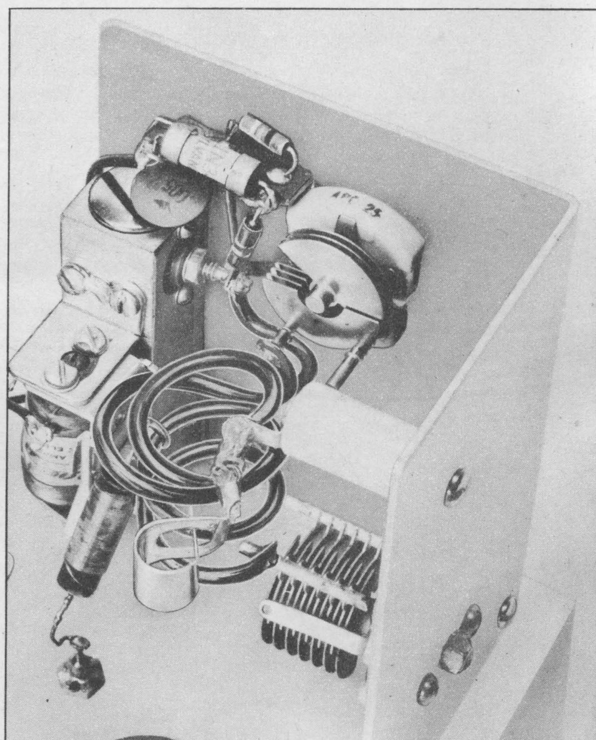
AC Power Supply

The power supply for ac operation is shown to the right of the transmitter unit in *Fig. 1;* the schematic diagram for this supply is shown in *Fig. 7.* This supply is constructed on a 5 by 10 by 3-inch chassis. It employs a conventional full-wave rectifier and filter circuit, plus a selenium rectifier which supplies 6 volts dc for relay operation. The relay shown in *Fig. 7* is a control relay which simultaneously grounds the center tap of the high-voltage winding of the power transformer and applies energizing voltage to the antenna relay when the microphone switch is closed.

Genemotor Power Supply

For mobile and emergency operation, the power unit shown in the upper left-hand corner of *Fig. 1* should be connected to the octal chassis

Fig. 5. Closeup view of the tank circuit.



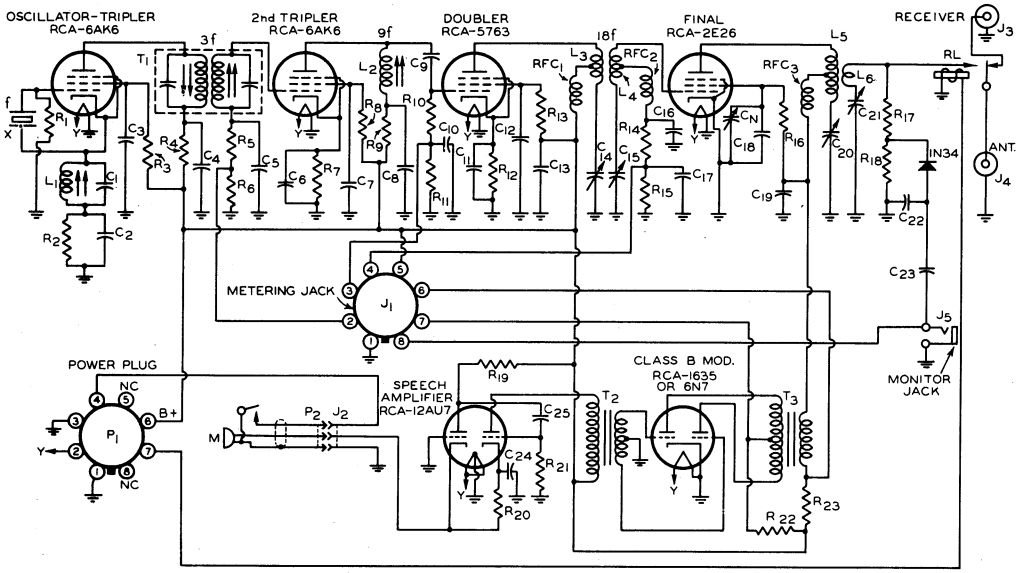


Fig. 6. Schematic diagram of the transmitter.

connector P_1, located on the transmitter. This supply employs a Genemotor which operates from a 6-volt storage battery to provide a plate voltage of 300 volts. The output of the Genemotor is filtered with a single 4-μf capacitor. A control relay is also included in this supply as shown in the schematic diagram, *Fig. 8.* When the microphone switch is pressed, this relay connects the ungrounded input terminal of the Genemotor to the "hot" side of the storage battery, and simultaneously applies energizing voltage to the antenna relay. A 5 by 9½ by 2-inch chassis is required for the construction of this power supply.

Installation Notes (Mobile Operation)

For mobile operation, the transmitter and the Genemotor supply should be fastened securely to a shock-mounted support. A piece of ¾-inch plywood and four shock mounts will serve as a simple vibration-proof mounting.

Connection to the car battery should be made through a heavy conductor to minimize voltage drop. If the transmitter is installed in the trunk of the car, a No. 4 flexible cable is recommended; a No. 6 conductor is adequate if the length is four feet or less.

Check the polarity of the auto battery and determine the polarity of the grounded terminal. As shown in *Fig. 8,* the negative input terminal of the Genemotor is grounded. *If the positive terminal on the battery is grounded, reverse the input connections to the Genemotor.*

Since the details of the mobile installation will vary with the type of vehicle and also with individual preferences, the control circuit for the application of heater voltage has not been included in the dc supply. Heater voltage should be controlled by means of a 6-volt, SPST relay with ¼-inch contacts connected in series with the "A hot" input terminal of the Genemotor supply and the ungrounded battery terminal. Energizing voltage to the coil of this relay may be controlled by a SPST toggle switch located at the operating position.

Operation

With the ac power supply connected to P_1, heater voltage will be applied to the tubes in the transmitter when the power supply switch is turned on. Closing the microphone push-to-talk switch will simultaneously apply plate voltage to the transmitter tubes and cause the antenna-transfer relay to operate, regardless of the power supply employed.

Table II — Currents and Voltages for Normal Operation*

Meter Indication	Oscillator Tripler (6AK6)	Second Tripler (6AK6)	Doubler (5763)	Final (2E26)	AF Amp (½ 12AU7)	Driver (½ 12AU7)	Modulator (1635)
E_b (v)	275	265	300	300	300	300	300
I_b (ma)	12	15	35	60	4	7	6 (min.) 40 (max.)
I_{c2} (ma)	2.3	3.0	2.5	5.0	—	—	—
E_{c2} (v)	195	165	250	200	—	—	—
I_{c1} (ma)	0.7	2	0.9	1.6	—	—	—
E_k (v)	12	20	1.5	0	4	11	0

* *For rf output of 10 watts.*

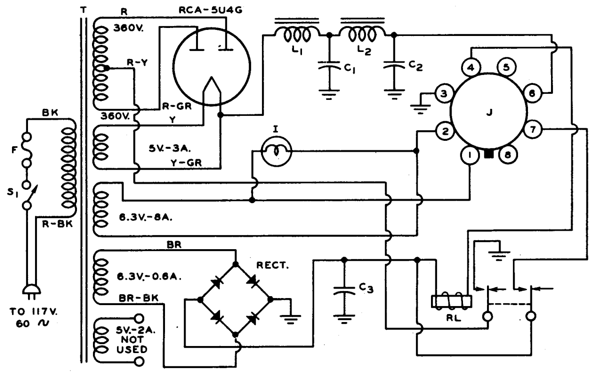


Fig. 7. Schematic diagram of the power supply for the fixed-station installation.

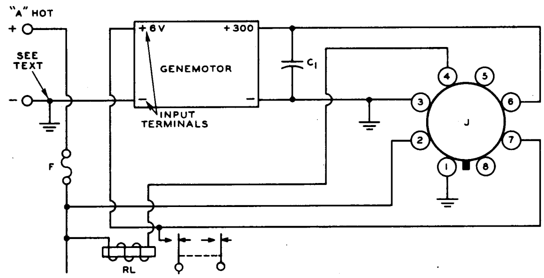


Fig. 8. Schematic diagram of Genemotor power supply for the mobile installation.

Transmitter

- C_1 100 $\mu\mu$f.
- C_2 0.005 μf, disc ceramic.
- C_3, C_4 Twin 0.004 μf, disc ceramic.
- C_5 0.005 μf, disc ceramic.
- C_6, C_7 Twin 0.004 μf, disc ceramic.
- C_8 0.005 μf, disc ceramic.
- C_9 10 $\mu\mu$f.
- C_{10} 0.005 μf, disc ceramic.
- C_{11}, C_{12} Twin 0.004 μf, disc ceramic.
- C_{13} 0.005 μf, disc ceramic.
- C_{14} 25 $\mu\mu$f, air padding.
- C_{15} 25 $\mu\mu$f, air padding.
- C_{16} 100 $\mu\mu$f.
- C_{17} 0.005 μf, disc ceramic.
- C_{18} 47 $\mu\mu$f.
- C_{19} 470 $\mu\mu$f, feed-through type.
- C_{20} 25 $\mu\mu$f, air padding.
- C_{21} 25 $\mu\mu$f, air padding.
- C_{22} 0.005 μf, disc ceramic.
- C_{23} 0.01 μf, 400 wv.
- C_{24} 25 μf, 25 wv, electrolytic.
- C_{25} 0.005 μf, disc ceramic.
- C_N 4-30 $\mu\mu$f, ceramic.

- J_1 8-pin octal socket.
- J_2 Amphenol connector PC2F.
- J_3 Coaxial connector type N } part of coax relay R_L.
- J_4 Coaxial connector type N } part of coax relay R_L.
- J_5 Phone jack.

- L_1 RCA 202L1, TV picture if coil.
- L_2 5 turns 14E on ½-in. diam, spaced to fill winding space of 11/16 in. on National XR50 form.
- L_3 5 turns 14E on ½-in. diam; space between turns equal to wire diam.
- L_4 3 turns 14E on ½-in. diam; space between turns equal to wire diam.
- L_5 3 turns 10E on ¾-in. diam; spaced to occupy 1½ in.
- L_6 Single turn 10E on 1-in. diam.

- M Carbon microphone with "push-to-talk" switch.

- P_1 8-pin octal plug.
- P_2 Amphenol connector MC2M.

- R_1 100,000 ohms, ½ watt.
- R_2 1,000 ohms, ½ watt.
- R_3 47,000 ohms, ½ watt.
- R_4 1,000 ohms, ½ watt.
- R_5 33,000 ohms, ½ watt.
- R_6 1,000 ohms, ½ watt.
- R_7 1,000 ohms, ½ watt.
- R_8 47,000 ohms, ½ watt.
- R_9 1,000 ohms, ½ watt.
- R_{10} 82,000 ohms, 1 watt.
- R_{11} 1,000 ohms, ½ watt.
- R_{12} 68 ohms, ½ watt.
- R_{13} 22,000 ohms, 1 watt
- R_{14} 33,000 ohms, 1 watt.
- R_{15} 1,000 ohms, ½ watt.
- R_{16} 20,000 ohms, 1 watt.
- R_{17} 15,000 ohms, ½ watt.
- R_{18} 10,000 ohms, ½ watt.
- R_{19} 47,000 ohms, ½ watt.
- R_{20} 1,000 ohms, ½ watt.
- R_{21} 470,000 ohms, ½ watt.
- R_{22}, R_{23} 10 ohms, ½ watt.

- RFC_1, RFC_2, RFC_3 40-in. length of 32E wound on ¼-in. diam. form.

- R_L Advance 8500, 6-volt type or equivalent.

- T_1 RCA 206K1, TV sound if transformer.
- T_2 Thordarson T20D76 or equivalent.
- T_3 Thordarson T21M52 or equivalent.

AC Power Supply

- C_1 40 μf, 450 wv, electrolytic.
- C_2 80 μf, 450 wv, electrolytic.
- C_3 3,000 μf, 15 wv, electrolytic.
- F 5-ampere fuse.
- I 6-v, 150-ma pilot lamp.
- J 8-contact octal socket.
- L_1 Choke, 3 henrys at 225 ma, Peerless C-315-X or equivalent.
- L_2 Choke, 5 henrys at 200 ma, Stancor C-1646 or equivalent.
- R_L Relay, 6v (dc), Advance 500 or equivalent.
- RECT Selenium rectifier, 600 ma, 25v, Federal 1017.
- S_1 SPST Toggle Switch.
- T Power transformer, RCA 201T8.

Genemotor Power Supply

- C_1 4 μf, 450 wv, electrolytic.
- F 30-ampere fuse.
- G Carter Genemotor 325-A or equivalent: input 6v, 21 amp; output 300v, 250 ma.
- J 8-contact octal socket.
- R_L Relay, 6v(dc), Advance 500.

Keying the Beam-Power Phone Final*

By

J. H. Owens, W2FTW**

By the installation of a single control tube and a few resistors, practically any beam-power phone transmitter can be converted for cw operation. And when the key is down, the final is just as suitable for plate-and-screen modulation as it was before the keying system was added.

In addition to providing a clean-cut cw signal that is free from chirps, thumps, and key clicks, this unique system offers worthwhile advantages over some of the keying systems presently in use.

BASICALLY, the new method is simply an adaptation of the well-known cathode-return keying system popularly used in triode finals. It differs by the use of a unique method of preventing the screen-grid voltage from exceeding tube ratings when the key is in the up position. With this system, the screen-grid voltage is reduced below the cathode voltage, thereby completely cutting off the plate current in the final amplifier; consequently, the back-wave signal is not transmitted.

For purposes of illustration, this keying system is described here as applied to a typical low-power final employing a single 807. The circuit diagram is shown in *Fig. 1.* A 6AQ5 miniature beam-power tube is used in the control-tube circuit.

The dc plate resistance of the 6AQ5 can be made either very low or practically infinite, depending upon whether the key is up or down, respectively. Because the plate of the 6AQ5 is tied directly to the screen-grid of the final-amplifier tube, the 6AQ5 performs electronically and instantly the service of a relay without the delay, sparking, and other difficulties sometimes encountered with relays in high-speed circuits.

The system is also applicable to both phone and cw transmitters employing tetrodes or pentodes.

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Key-down Position

The operation can best be understood by examining the circuit in the key-down position. The cathode of the final is at ground potential, being by-passed for rf through C_2, while the dc return is through R_5 (a few ohms) and the key. The plate current of the 6AQ5 is practically cut off because the screen-grid of this tube is connected to the same ground-return circuit. The control-grid of the 6AQ5 is connected through an isolating and filtering resistor to the grid side of the grid-bias resistor of the final amplifier, a negative-voltage point. The combined effects of high negative bias on the control-grid and substantially ground potential on the screen-grid raise the dc plate resistance of the 6AQ5 to near infinity. Thus, for all practical purposes, the 6AQ5 has absolutely no effect on the final amplifier which operates as if the control-tube were out of the circuit. Obviously, when the key is down, the final amplifier can be plate-and-screen modulated the same as before the control circuit was installed.

Key-up Position

When the key is in the up position, entirely different conditions prevail. The open key removes the dc ground return from the final-amplifier cathode and the 6AQ5 screen-grid, and both of these electrodes become positive as a result of voltage being applied through R_3. At the same time, the control-grid of the 6AQ5 becomes slightly positive because it is connected to the final amplifier cathode through isolating resistor R_2, the grid-bias resistor R_{11}, and the grid milliammeter M_1. Although grid current continues to flow through the final amplifier grid-bias resistor, the negative voltage across this resistor is con-

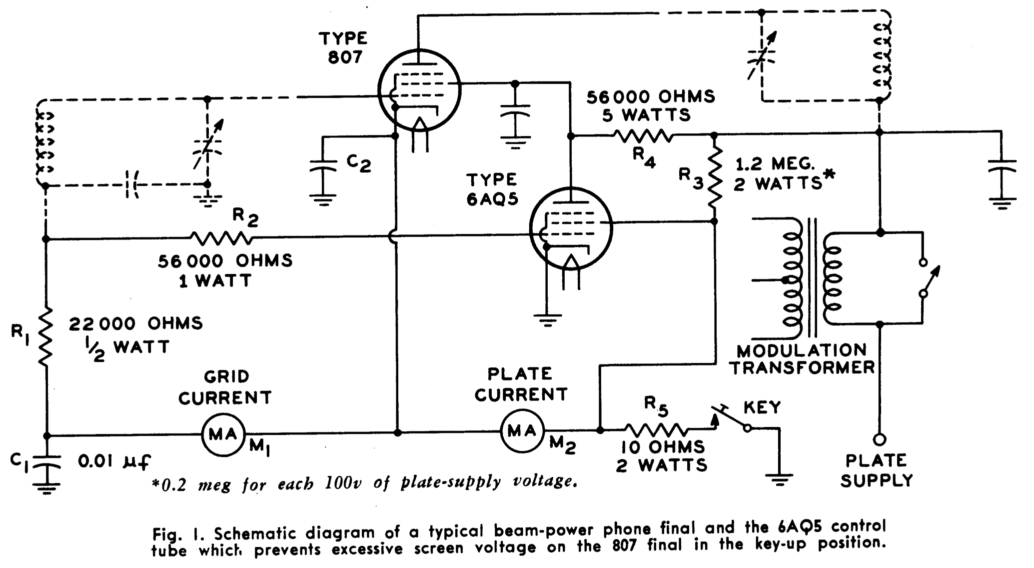

Fig. 1. Schematic diagram of a typical beam-power phone final and the 6AQ5 control tube which prevents excessive screen voltage on the 807 final in the key-up position.

siderably less than the positive voltage between the final-amplifier cathode and ground; therefore, the net potential at the top of the grid-bias resistor is positive.

This voltage is applied to the control-grid of the 6AQ5 through isolating resistor R_2, but the low resistance of the positive 6AQ5 grid and the high resistance of the isolating resistor cause a relatively large voltage drop; hence the grid of the 6AQ5 is slightly positive. The combined effects of slightly positive bias on the control-grid, and the substantial positive voltage on the screen-grid reduce the dc plate resistance of the 6AQ5 to a low value. The plate of the 6AQ5, being tied to the final-amplifier screen grid, puts a heavier load on the screen-grid dropping resistor R_4 than does the screen grid of the final amplifier; therefore, the voltage on this screen is greatly reduced when the key is in the up position. In fact, it is reduced below the cathode voltage, and this, plus the negative bias applied between cathode and the control-grid, serves to cut off the final-amplifier plate current. The overall effect is that the screen-grid of the final amplifier is protected and the rf signal is interrupted.

Circuit Details

Note the location of the grid and plate meters in the circuit. This arrangement provides the least amount of interaction without having the plate-current meter in the high-voltage circuit. As connected, milliammeter M_2 indicates the sum of the plate and screen currents. The grid meter, M_1, indicates the dc grid current. (As previously mentioned, grid current continues to flow when the key is up.) The grid current is practically the same when the key is down.

The values for the three added resistors (R_2, R_3, and R_5) are given in the schematic diagram; actual values are not critical. Resistor R_2 is simply an isolating resistor to keep rf off the 6AQ5 control-grid. Resistor R_5 is a key-click suppressor. Resistor R_3 applies positive voltage to the final cathode and 6AQ5 screen-grid; its value may be halved or doubled for experimental trials. Resistor R_4 is the screen-grid dropping resistor.

A 6AQ5 keying tube is satisfactory for an 807 or 829-B. If one or two 813's are used in the final rf amplifier, a 6V6-GT or 6F6-G should be substituted for the 6AQ5. The actual resistance and power rating of R_3 will vary with the plate-supply voltage.

It is good practice to short out the secondary of the modulation transformer when a phone transmitter is keyed. Switch S_1 is included in the circuit for this purpose.

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A comprehensive listing of articles on TVI and related topics. Although the articles appearing in the non-amateur publications contain only brief mention of the amateur and TVI, they have been included to supply the advanced amateur with a complete set of references. A few important articles on interference from sources other than amateur transmitters as well as some editorials have been listed. Radio amateur groups will find the editorial articles valuable references for discussions. Note that the articles are listed in chronological order; this has been done to facilitate retrospection, and to permit easy cross reference to TV reception techniques and improvements.

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Joseph Pastor, Jr.,
Editor **W2KCN**

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"The Big Hunt"
De-TVling a 600-Watt, 14-Mc Transmitter

By

C. A. West, W2IYG†

After considering the great deal of time and effort which must be spent on the solution of TVI problems, the amateur is justified in taking time out to consider such activities objectively, especially with respect to the definition of the word "hobby." Indeed, TVI problems offer an interesting challenge to the ham who has an above-average technical background—but then the effort spent on study, experiments, and redesign can be greater than that which he expends on his vocation. With the basic purpose of a hobby in mind, i.e. relaxation, this TVI story by W2IYG departs from the style generally followed for technical articles.

THE de-TVIing of an amateur transmitter can be likened to a hunting trip. However, unlike the average sportsman, I cannot truthfully admit that I looked forward to the hunt. Frankly, the pursuit and capture of certain game ("game" being represented by spurious TVI-producing radiations) was motivated only by the generous bounty offered—carefree operation without TVI complaints.

For obvious reasons I refer to these interfering radiations as "beasties," and identify them by numbers (until they can be classified, according to species, and given scientific names). Those most numerous in the New York TV service area are beasties 2, 4, 5, 7, 9, 11, and 13.

It would be unfair to liken these obnoxious critters to any member of the animal kingdom. Actually, no man has ever seen a TVI beastie with the unaided eye; they can only be observed by means of a kinescope!

Although their natural habitat is the rf, if, and video stages of TV receivers, some beasties have been encountered in the audio stages.

History tells us that some of the early pioneers managed to capture beasties by means of traps (circuits, that is). Mechanical traps (shielded cabinets) have been found effective; however, Bring-'em-Back-Attenuated Seybold, W2RYI, has conducted many experiments to show that the elusive beastie can, among other things, escape from a metal cabinet—right through the cracks between panels!*

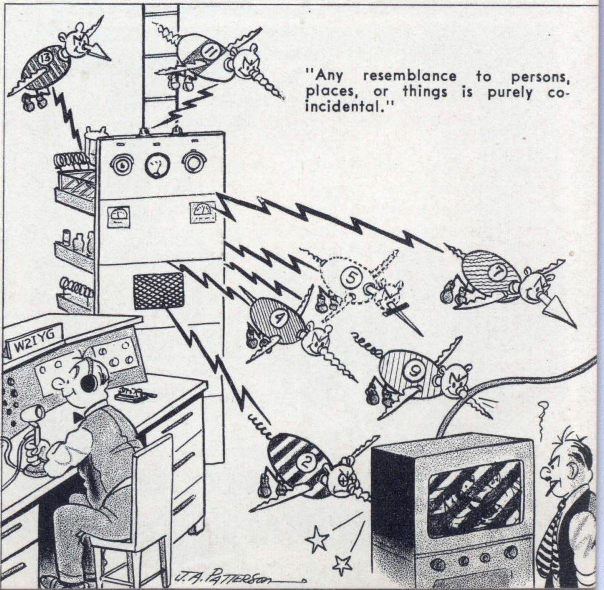
Description of the Pre-TV Transmitter

The 600-watt, 14-Mc transmitter at W2IYG, mounted in a conventional, unshielded, open-type rack, did not employ any anti-TVI devices. The line-up included a converted BC-696 as a 3.5-Mc, VFO-exciter with a 1626 oscillator, and a 1625 keyed amplifier stage. This unit was connected by coaxial cable to the main transmitter which employed a 6L6 operating as a 7-Mc, 8-watt, grounded-grid doubler, and an 828 operating as a 14-Mc, 100-watt buffer-doubler driving an 833-A final amplifier.

Before this hunt began, I used various evasive tactics to avoid the beasties—live and let live. Many hams are no doubt using such tactics as "quiet-hour" operation, operation during the wee hours of the morning while the kinescopes are

†RCA Tube Dept., Harrison, N. J.

*"Shielding Experiments and TVI," by A.M.Seybold, W2RYI CQ, June 1949.



de-energized, etc. As the months rolled by, new TV antennas appeared nearer and nearer my humble abode. The beasties seemed to love the gadgets which people were having mounted on their roof tops, chimneys, window sills, and even within their homes. I realized that I must either hunt these beasties or else find myself being hunted by the neighbors!

TVI Checks

To bring the beasties within range so that I could study their characteristics, I employed a receptor device (a commercial TV receiver). Interference on my unfiltered TV receiver was very severe on channels 2 and 4, diminishing in severity through channels 5, 7, and 9. My TV set is located in a room directly under the shack. The TV antenna is situated in the attic about six feet below my 600-ohm transmission line for the 3-element, 14-Mc rotary beam, mounted on the roof of the house.

The pictures, and sound on channels 2 and 4 were completely gone. Channels 5, 7, and 9 fared a little better in that sound was available. The picture for channel 5 was almost washed out, the picture for channel 7 was somewhat better, and channel 9 displayed even further improvement; channels 11 and 13 were unaffected. The addition of a commercial high-pass filter had little effect in clearing up the interference. Telephone calls indicated that my transmitter was interfering with reception on TV receivers located up to ¼ mile from the transmitter. A test with a ham located at this distance confirmed these reports. He reported that interference was severe on channels 2, 4, and 5.

To become familiar with the beasties, I laboriously studied the extensive and detailed reports of others who had sought out the beasties and had captured them.* These successful hunters used many methods and various devices with great success.

The first step in this anti-TVI campaign was the sifting of this wealth of information on TVI elimination to determine the basic methods for preventing and eliminating TVI. Simple tests were made to determine the nature and sources of the spurious radiations from the transmitter; and finally, a study was made to determine the simplest method of obtaining TVI-free operation of the transmitter.

**See "TVI Bibliography" in the Winter 1950-'51, and Spring 1951 issues of HAM TIPS.*

Checking for Spurious Radiations

The existence of harmonics in the output of the average oscillator, frequency multiplier, or class C amplifier, can be easily verified because their frequencies are known, i.e., they are integral multiples of the fundamental frequency. Interfering signals from the transmitter, that fall within a TV channel, but whose frequencies are not harmonically related to the fundamental, are usually generated by parasitic oscillations.

Very-high-frequency parasitics can be as troublesome as very-high-frequency harmonics. Actually, the damaging results are the same in either case. Very-high-frequency parasitics can occur in any rf stage due to feedback within the tube (at some frequency other than the fundamental), when lead inductances and stray capacitances in the grid and plate circuits resonate at the same or nearly the same frequency. Many of the rules which apply to the reduction of harmonics apply here also.*

In spite of careful design and construction, very-high-frequency parasitic oscillations may occur. The following simple method was used to check each stage to determine whether parasitic oscillations were present: With the rf excitation removed from the stage being checked, and with all normal voltages applied, the grid bias for this stage was adjusted to the value where static plate current began to flow (without exceeding the plate-dissipation rating of the tube).

Plate current was then observed while the tank capacitor was varied through its range. The absence of sharp changes in plate current during this check indicated that parasitic oscillations were absent. A grid-dip oscillator is recommended for determining the frequency of the parasitic oscillation.** (When a grid-dip oscillator is used, be sure that all voltages are removed from the circuit.)

To determine whether fundamental oscillation was occurring in the stage being checked, a receiver was tuned through the frequency of the fundamental. The presence of a signal would indicate that this stage required further neutralization.

Inasmuch as the output of the transmitter did

**"The Pursuit and Elimination of Parasitics," by W.I.Orr, W6SAI, CQ, Dec. 1950.*

***The elimination of parasitics has been treated very thoroughly in various publications. The amateur handbooks are excellent references.*

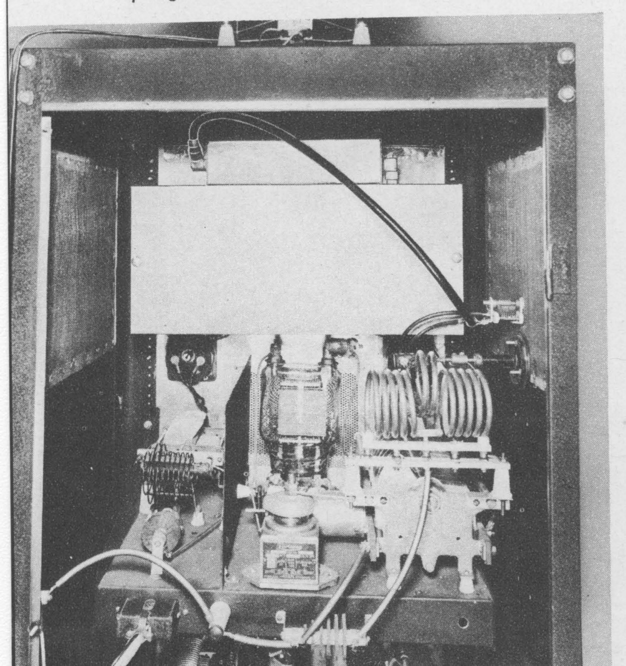


Fig. 1. Rear view of the shielded transmitter. Note the 56-Mc series trap on the plate cap of the 833-A, the louver shielding, and the paint-free edges of the cabinet for contact with the rear door (removed). The high-voltage capacitor on the left-hand side of the cabinet bypasses a B+ lead from an external modulator. The shielded box directly above the final amplifier contains the antenna coupler which is connected by means of a right-angle, coaxial fitting to the low-pass filter (mounted on top of the coupler).

not contain any parasitics, it was evident that harmonics were being generated in the transmitter. The strongest harmonic was causing severe interference on channel 2. The sources of the harmonics were located by noting the changes in interference on a nearby TV receiver as the final, buffer, and each of the exciter stages were disconnected, in turn. This check disclosed that the 833-A final was generating the strong channel-2 harmonic which interfered with reception on my neighbor's set, and that all stages were causing some interference.

How to de-TVI? (Modification vs Rebuilding)

After reading the literature on TVI, I was tempted to completely rebuild the transmitter; however, I gave serious thought to avoiding this drastic step because it meant tearing down an efficient transmitter. Nevertheless, the TVI problem had to be solved. With an open mind, I studied the constructional details of the transmitter and then carefully weighed the merits of rebuilding against those for modification.

Rebuilding. A new design for a TVI-free rf section would have to be based on the following factors:

1. Selection of a single-ended class C amplifier, instead of a push-pull stage, for lower second-harmonic output.[1]
2. The use of a final-amplifier tube of the tetrode or pentode type—an easy-to-drive tube eliminates the necessity for numerous exciter stages.
3. The utilization of a pi-type tank circuit for additional attenuation of harmonics.[2]
4. The use of low-capacitance, high-voltage capacitors connected between the plate and cathode (or filament) in rf stages (especially the high-power stage) to provide an effective and relatively simple means of reducing very-high-frequency harmonics generated in these stages.[3]
5. Minimum number of frequency multipliers.
6. Restriction of frequency multiplication to very-low-power stages if several frequency multipliers are required because of low-frequency VFO control.

Modification. To be made TVI-proof, it is necessary that the transmitter modifications:

1. Provide the necessary shielding to prevent direct radiation from the circuits.
2. Prevent the generation of harmonics.
3. Attenuate all very-high-frequency components (lying within the portion of the spectrum allocated to TV) in the output.
4. Prevent cables and leads, located outside the cabinet, from radiating interfering signals.

An appraisal of the transmitter in the light of these modern design requirements revealed that this pre-TV transmitter lacked all of these essentials for TVI-free operation. For example, the open-type rack did not provide the necessary shielding, and the meters required shielding to prevent them from radiating.

Because channel-2 interference was the strongest, much improvement could be effected by means of a 56-Mc trap in the tank circuit of the final amplifier. (Quite possibly, one of the other beasties may be causing you as much or more trouble. If this is the case, the parallel-tuned, series plate trap should be tuned to the beastie's frequency.) Harmonics which occur in each rf stage, and fall within the TV channels, should be suppressed as much as possible at their source.*

Planning the Hunt

Being an active DX man, I wanted to complete the TVI-elimination project in the shortest possible time. The object of this project was to solve the TVI problem without employing any cut-and-try methods. Because this requirement ruled out any time-consuming experimenting, a thorough job of TVI elimination could be assured only by the application of *all* of the basic methods for de-TVIing a transmitter.

Careful evaluation of the various TVI-elimination techniques revealed that I must use the following weapons: (1) shielding, (2) lead filtering, (3) output filtering by means of a low-pass filter, and (4) modification of rf circuits.

The Hunt

Girding my hunting gear, I set forth with confidence and determination. The details of the hunt are as follows:

A parallel-tuned, 56-Mc series plate trap in the final amplifier, and a six-section, M-derived, low-pass filter (together with an antenna coupler) were employed to obtain an attenuation of approximately 150 db. This attenuation was sufficient for beastie No. 2, the most troublesome of all, and more than adequate for the other beasties.

It cannot be emphasized too strongly that, to obtain this very desirable attenuation, it is extremely important that shielding and lead filtering be as near to perfection as possible. The following procedures describe the simple and straightforward steps which were followed to completely de-TVI the transmitter:

Shielding

The use of the open-type relay rack, having individual shielding of each rf unit, was seriously considered. However, this idea was discarded because many filter circuits would be required for the various leads connecting the individual rf units. Also, shielding of the individual rf units was avoided because each unit would require a specially shielded door to provide access to the plug-in coils.

Shielding provided by a conventional enclosed rack is insufficient for a TVI-proof transmitter because of the openings provided for ventilation, the cracks between panels, and those between the door and cabinet. Also, effective slots exist between overlapping metal surfaces wherever a layer of paint causes a separation of the parts of the cabinet.** Consequently, the entire transmitter (including power supplies), the low-pass filter, and the antenna coupler were mounted

---

[1] *"Down With Harmonics," by J.H.Owens, W2FTW, CQ, Feb. 1948.*

[2] *"Pi-Network Tank Circuits," by E.W.Pappenfus, WΦSYF, and K.L.Kilppel, WΦSQD, CQ, Sept. 1950.*

[3] *"More on TVI Elimination," by P. S. Rand, W1DBM, QST, Dec. 1948. "TVI Tips," QST, Oct. 1949.*

* *"Don't Pamper Your Harmonics," by P.S.Rand, W1DBM, QST, Feb. 1950.*

** *Each slot can radiate because it is equivalent to an antenna whose length is equal to the length of the slot.*

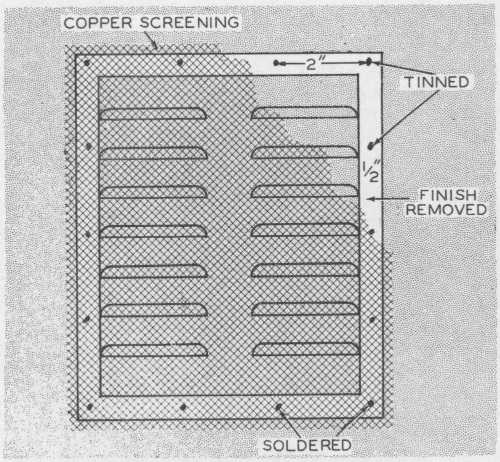


Fig. 2. Louver shielding details.

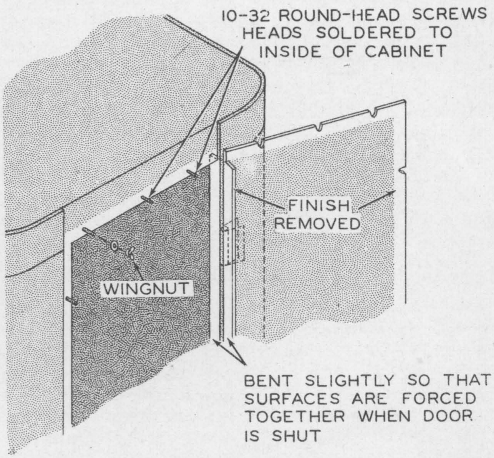


Fig. 3. Scheme employed to insure metal-to-metal contact between the door and rear edges of the enclosed rack.

within a modified enclosed rack.

In my particular case, I believe that shielding was the most important factor in reducing TVI because:

1. Thorough shielding provided by the modified enclosed cabinet prevents direct radiation from rf stages.
2. Shielding permits the external line filters and low-pass filters to function without interference from rf fields.
3. Complete shielding permits the use of unshielded and unfiltered leads within the cabinet.
4. Conventional circuits can be used in the exciter stages without resorting to critical constructional details and circuit arrangements.

Cabinet Alterations

The areas of overlap of the various parts of the cabinet were defined with the aid of a china-marker crayon. The cabinet was disassembled and paint remover applied with a small brush to those marked areas which were in contact when the cabinet was assembled. The softened crackle finish was then removed with a wire brush and the marked area was wiped dry with a clean cloth.

Shielding of the louvers was accomplished as follows: A frame-shaped area was marked around the louvers as shown in *Fig. 2,* and the paint was removed from the area. After the metal surface was thoroughly cleaned, a 500-watt soldering iron was employed to tin small areas located every two inches along the frame-shaped area.

Copper shielding, slightly larger than the outer dimensions of this frame-shaped area, was soldered to the previously tinned areas. For a smooth neat job, the screening was pulled up tightly before each point was soldered.

The cabinet was then reassembled with the paint-free areas making contact; the problem of providing metal-to-metal contact between the door and the cabinet was solved as follows: The paint was removed from the inside edges of the door and from the rear edges of the cabinet, along the entire area where the door overlapped the edges of the cabinet. (See *Fig. 3.)*

Since the door was not rigid enough to fit flush against the rear edges of the cabinet, a reasonably tight joint between the door and the cabinet was obtained by employing the scheme illustrated in *Fig. 3.*

The holes for the bolts are spaced about 10 inches apart along the rear edges of the cabinet. Roundhead 10-32 screws, a half-inch long, were inserted from the inside of the cabinet and the heads soldered in place on the inner surfaces. Holes were then drilled in the door to allow these screws to pass through when the door was closed. Wing-nuts were used to pull the door up tightly against the rear edges of the cabinet. Shielding at the hinge edge of the door was accomplished as shown in *Fig. 3.*

Cracks between panels were covered with strips of ordinary household aluminum foil (cut to a width of one inch) held in place with adhesive tape as shown in *Fig. 4.*

It has been shown that it is equally important for all meters to be thoroughly shielded to prevent them from radiating. The meters were shielded quite effectively and simply as follows:

1. Each meter hole was enlarged to a diameter slightly greater than the diameter of the beaded edge around the front of the meter case.
2. Paint was removed from the back surface of the panel around the meter hole.
3. A piece of ordinary copper window screening was cut slightly larger than the maximum diameter of the meter hole, and the meter was fastened to the rear of the panel behind the screening as shown in *Fig. 4.* This screening did not obstruct vision of the meter face since it was bowed out slightly by the beading on the case, as the mounting screws were tightened. Some of the meters were flat faced (without the beading); the screens for these meters were bowed outward by pressing the end of a rounded screwdriver handle against the screens before the meters were fastened in place.

Lead Filtering

None of the leads within the cabinet were shielded. However, an L-type filter was connected to each lead leaving the shielded cabinet.*

**This lead filtering prevents rf feed-back, which may occur when rf is picked up by the 110-volt house wiring, through the various filament and power transformers to the VFO and high-gain audio circuits.*

Most of these leads are 110-volt power leads and 6.3-volt relay leads which were relatively simple to filter.

Filtering of these leads was accomplished as follows:

1. The 110-volt power leads were connected to simple L-type filters in a shielded compartment mounted on the outside of the transmitter cabinet as shown in *Fig. 6*. The coils have approximately 50 turns on 1½-inch diameter forms.* All inductors and capacitors were arranged to facilitate short wiring, and each capacitor was connected as close as possible to the point where the filtered lead passed through the shielded filter compartment.

2. For each low-current, low-voltage lead which supplies relay power, bias, or B+ voltage, where less than one ampere of current is flowing, an Ohmite Z-50 choke was employed together with a 0.1-μf capacitor. Voltage ratings for these capacitors are given in the Lead Filtering Data, *Table I*.

3. The L-type filter was used also for the high-voltage leads connected to the class B modulation transformer which was mounted in another relay rack. A 500-$\mu\mu$f, 10,000-volt television capacitor and an Ohmite Z-50 choke were employed in each of these filters.

The inductance values of these coils are not critical. Wire size should be selected on the basis of the current-carrying requirement.

Power for the VFO, located in the operating console, was obtained from a low-voltage power supply within the shielded transmitter cabinet. The outer shielding of the cables between these units were grounded directly to a point on the *inside* of the cabinet.*

Filtering of the Output

After shielding the transmitter and filtering

**To prevent radiation of any very-high-frequency harmonics which may be picked up by the outer conductors of the portions of these cables located inside the cabinet.*

Table I — Lead Filtering Data

Lead	Inductor, L		Capacitor, C	
	Inductance	Current Rating	Capacitance	Volt. Rating
Low-Voltage, Low-Current (Relays, etc.)	Ohmite Z-50	To 1 amp.	0.1 μf	At least twice the voltage appearing between the lead and ground
Low-Voltage, High-Current (110-volt power leads)	See Text	See Text	0.1 μf	
Med.-Voltage, Low-Current (B+, bias, etc.)	Ohmite Z-50	To 1 amp.	0.0005 to 0.1 μf	
High-Voltage, Low-Current	Ohmite Z-50	To 1 amp.	0.0005 μf	

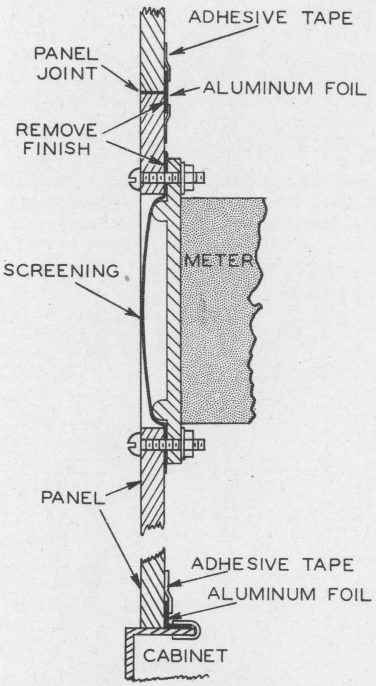


Fig. 4. Meter-shielding details and the simple method for sealing the cracks between panels.

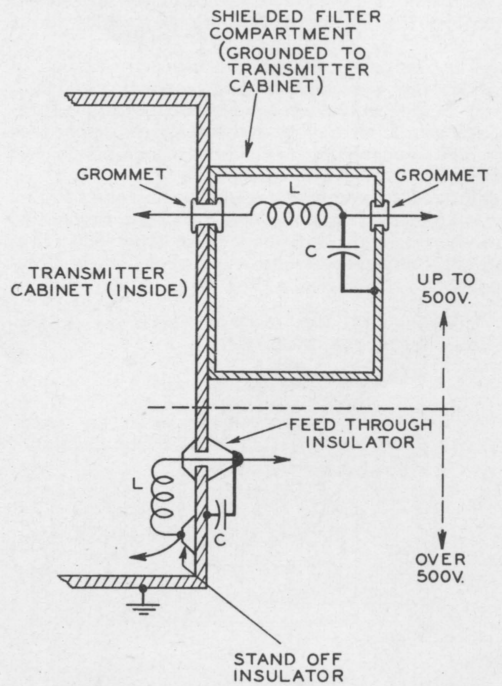


Fig. 5. Construction of lead filters for low- and high-voltage circuits.

I guess the trip to his TV receiver could be compared to the "last mile." You can imagine the suspense! As I walked down the street to his house, I began to recall the past few weeks of removing paint, scraping, filing, drilling, and soldering. Would all this be worth the effort? Would it be worth all the rare DX I had missed during the time I was off the air? I would soon have the answer.

I checked all channels on his TV set and found absolutely no interference on any channel. In a way, this was hard to believe, since a high-pass filter which I brought along was still in my pocket! Needless to say, my neighbor was just about as happy as I about the whole thing. My closest neighbor, about 50 feet away, reported he had no objectionable interference on his set.

Being interested in eliminating the channel-2 interference on my TV receiver, located in the room below the transmitter, I conducted further tests to determine which stage (or stages) of the transmitter was causing the trouble. The 600-watt 833-A stage was turned off without any noticeable interference reduction. Next the 14-Mc, 100-watt buffer-doubler was turned off, but the interference remained unchanged. Finally, the 7-Mc, 8-watt 6L6 frequency multiplier was turned off and no reduction in interference was noted. By the process of elimination, I knew that the 3.5-Mc, 8-watt VFO-exciter was the offender.

This unit is a converted BC-696 with a 1626 oscillator and single 1625 keyed-amplifier. With the key in the up position and the oscillator running, all traces of interference disappeared. The 3.5-Mc amplifier was causing the interference in spite of the fact that I had thoroughly shielded this unit. Feeling that there would probably be no interference from this VFO-exciter unit operating in the 3.5-Mc band with only 8 watts input, I had not observed the precaution of filtering the power leads as was done on the transmitter proper.

I traced the interference to the unfiltered power-supply leads for the VFO; these leads were radiating harmonics. This example illustrates the importance of lead-filtering when one wishes to reduce harmonic radiation to practically zero in close proximity of the transmitter, regardless of the power input or the frequency of operation.

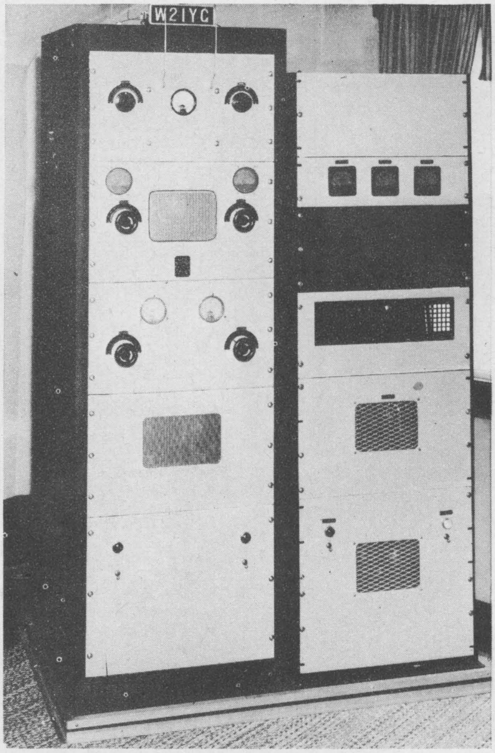
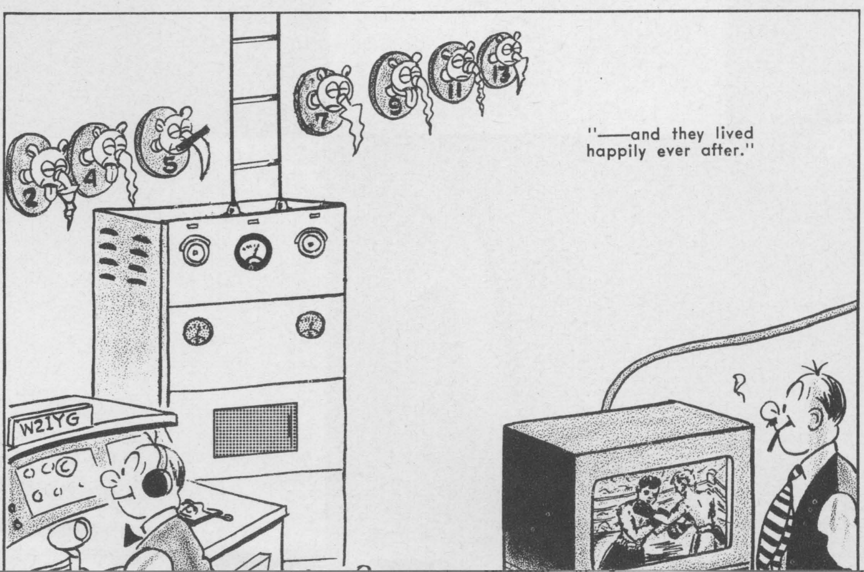


Fig. 8. Completely TVI-proofed and ready for operation. Before the transmitter was modified, the rf section (in the left-hand cabinet) was mounted in an open-type relay rack identical to the unshielded right-hand rack which contains the modulator. Observe the small-hole screen used in the panel-viewing windows in the rf rack. These windows were originally backed with the type of screening employed in the modulator rack. (The antenna meter did not require shielding because it was mounted in a shielded box enclosing the antenna coupler.)

The importance of shielding can be further emphasized by the following incident: One evening while I was working on the transmitter, with the rear door removed, my phone rang. It was a neighbor, five houses away, reporting interference on channel 2—and with the door on, he never knew when I was on the air!



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The "Twomobile" A 144-Mc Transceiver

By

H. W. Brown, Jr., W2OQN*

> Both portable and mobile operation are becoming increasingly popular, and the current Civil Defense mobilization program has done much to stimulate and intensify this trend. The transceiver described in this article, nicknamed the "Twomobile" for obvious reasons, has displayed excellent performance in mobile operation and is readily adaptable to fixed-station or portable installations. In mobile operation, the Twomobile has made 100 per cent solid contacts with fixed stations located 35 miles away—the power output is approximately 1½ watts.

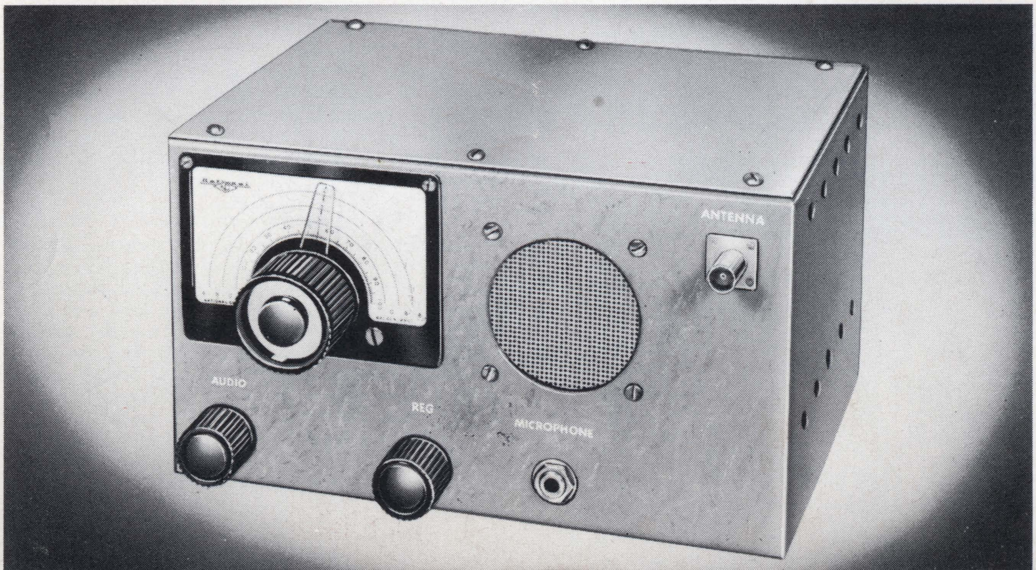
THE TWOMOBILE is a complete, compact, two-meter transceiver designed primarily for mobile application. Its carefully chosen tube lineup provides for efficient performance from a 250 to 300-volt, 100-ma vibrator-type power supply — power-supply drain, consistent with reasonable power output, was of prime consideration in the design of this unit.

The design of the Twomobile is quite straightforward and does not incorporate any complex or tricky circuits. The receiver section is a superheterodyne, using a superregenerative second detector. The transmitter section employs a 6AK6 tritet oscillator (with an 18-Mc crystal and 36-Mc output), a 6AK6 doubler, and a 5763 doubler-final.

During transmission, the receiver audio amplifier functions as the modulator. All switching from "transmit" to "receive" is accomplished by means of a three-pole control relay. Operation of this relay is controlled by means of a push-to-talk microphone switch. This relay, RL, switches the B+ voltage and the antenna from the receiver section to the transmitter section while simultane-

*RCA Aviation Engineering Dept., Camden, N. J.

Fig.1. The Twomobile—a straightforward, efficient transceiver for mobile operation.



ously opening the speaker voice-coil circuit and completing the ground connection to the cathode resistor of the final.

Receiver

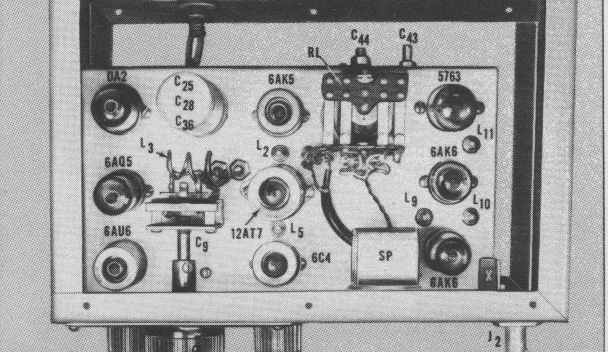
As shown in the receiver portion of the schematic diagram, it is apparent that the front end is of conventional design comprising a 6AK5 rf stage and a 12AT7 mixer-oscillator. The rf and mixer stages are both fixed tuned, thereby eliminating the usual bothersome tracking problem. At the frequencies that these stages operate, the operating Q of each coil is inherently low and little is to be gained by adding any extra tuning. Instead, these circuits are peaked to the approximate band center. A Hartley oscillator has been found to provide the best results in this frequency range. With the specified values of grid resistance and capacitance, the oscillator did not exhibit any tendency to superregenerate — a condition which so often plagues high-frequency oscillators. A one-inch length of 75-ohm twin lead, connected between the mixer and oscillator grids, serves as a coupling capacitor, providing optimum oscillator injection voltage.

The mixer plate is shunt fed through a 100-μh rf choke and is capacitance coupled to a 6C4 superregenerative detector. The choke is used instead of a resonant circuit, with some sacrifice in selectivity, due to the inherent difficulties, including "suck-outs," of coupling to this type of circuit.

The use of this detector has several advantages over a conventional intermediate-frequency system, especially for mobile work. It combines high sensitivity with desirable space- and component-saving features. At least three if stages would be required to provide the same gain. The selectivity is considerably less; however, in the interest of compactness, the loss of selectivity is a justifiable sacrifice. In this application the superregen's inherent avc and noise-limiting action is highly desirable. A squelch filter, consisting of C_{18}, C_{19}, and L_7, completes the detector circuit.

In a receiver of this type, the selection of the intermediate frequency is quite flexible, there being only one tuning adjustment, L_5, to consider. During the breadboard phase of the Twomobile design, frequencies between 10 and 75 Mc were tried satisfactorily. Although an intermediate frequency of 30 to 35 Mc appears to be optimum for satisfactory operation of the superregenerative detector, the use of a frequency in this range can present an interference problem (TVI in reverse) if the image frequency falls within a TV channel.

Fig. 2. Top view of the Twomobile. Note that this layout of components permits maximum utilization of the chassis area, and provides plenty of space between components for adequate cooling.



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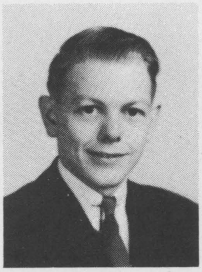


H. W. Brown, Jr., W2OQN

Wally has been a ham for more than fifteen years, operating first as W1KIQ from West Medford, Massachusetts. Upon graduating from Tufts College in 1942 with a BS in electrical engineering, he joined RCA Victor. In 1948, after spending six years as a design engineer in the Crystal Engineering Section, he transferred to the Aviation Engineering Department where he is now working on military communications equipment.

In the past few years he has written articles for *CQ* and HAM TIPS. A past president of the South Jersey Radio Association, Wally is currently on the board of directors, a member of its mobile emergency corps, and an enthusiastic participant in all its activities. His ham activities are primarily experimental, but schedules with his uncle, W1CWZ (who gave Wally his start in ham radio), keep his hand in on 40 and 80 cw.

His XYL is Madeleine, and they have two harmonics, Ronnie 10, and Peter 5. The Browns reside in Haddonfield, N. J.

In a high-signal area, such interference can be very annoying. To sidestep this problem, it was necessary to choose an intermediate frequency of 11 Mc even though the detector design became slightly more critical.

In actual practice, these images are usually low in signal level and, in many locations, cannot be heard. Outside the TV service areas, any convenient intermediate frequency may be employed. The image frequency may be calculated by subtracting twice the intermediate frequency from 144 (to 148) Mc. For those who prefer to experiment with various intermediate frequencies, one other more obvious precaution should be heeded: Select an intermediate frequency having harmonics which fall outside the two-meter band; i.e., do not employ the following frequencies: 24 Mc, 36 Mc, 48 Mc, etc. If a higher intermediate frequency is selected, detector coil L_5 should have a smaller number of turns, and the values of R_{10} and C_{16} should be changed to obtain the optimum quench frequency.

Audio Circuits

The first audio stage in the receiver section employs a resistance-coupled 6AU6. Since this audio system is also employed as a modulator, rf filters (R_{15}-C_{21} and L_8-C_{23} in the grid and cathode circuits, respectively, of the 6AU6) are incorporated to prevent rf pickup and resultant feedback during transmission. A 6AQ5 audio-output stage and a two-inch, permanent-magnet speaker provide a good working audio level.

During transmission, the receiver rf stages are disabled by means of relay RL which transfers

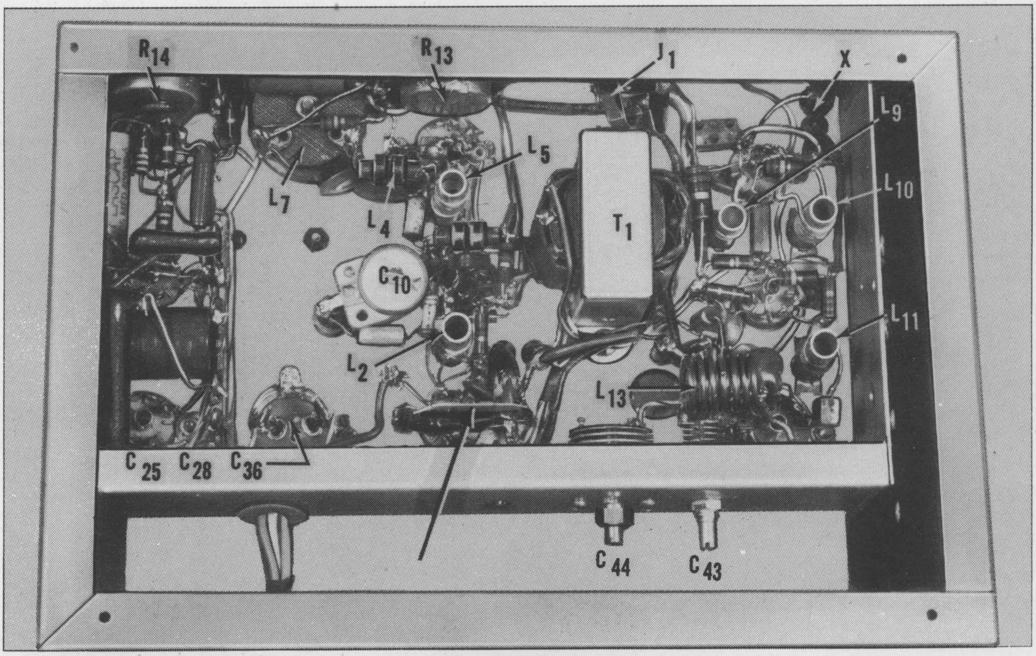


Fig. 3. Bottom view of the Twomobile. Note the accessibility of the components. Arrow points to a copper shield provided on the 6AK5 socket to prevent self oscillation of the rf amplifier.

the plate voltage to the oscillator and doubler tubes. A second set of relay contacts opens the voice-coil circuit of the speaker and grounds the cathode resistor of the 5763 doubler-final. Excitation for a carbon microphone is obtained from the cathode returns of the first two transmitter stages, and the microphone audio output is fed to the cathode of the 6AU6 audio amplifier. Only half of the primary of the push-pull output transformer is used during reception. During transmission, the plate current of the final flows through the other half of the winding. This arrangement tends to minimize the possibility of core saturation.

Transmitter

The oscillator employs the familiar tritet circuit using a 6AK6 and an 18-Mc crystal. In the Twomobile, frequency multiplication in any one stage is limited to doubling. An 18-Mc crystal was chosen because it is the highest-frequency crystal that is generally available at comparatively low cost.* Some suppliers do not keep 18-Mc crystals in open stock, but they can obtain them on special order, ground to any desired frequency. (The crystal used in this transmitter was received within two weeks from the time the order was placed.) A 12-Mc crystal, and tripling in the oscillator to 36 Mc, would possibly work satisfactorily, but driving power would be sacrificed. If this arrangement is desired, it is necessary to add a few turns to L_9.

The oscillator plate tank, L_{10}, is tuned to 36 Mc and is coupled to the 6AK6 doubler through capacitor C_{34}. In order to hold the capacitance appearing across the 72-Mc tank to a minimum, a balanced coil is used. This circuit is equivalent to a conventional split-stator tank circuit in that the 6AK6 plate capacitance and the 5763 grid capacitance are equivalent to the respective sections of a split-stator capacitor. This balanced tank-circuit arrangement provides appreciably more drive to the final than would be available from an unbalanced circuit.

A 5763 doubler does an excellent job as the output power amplifier. Here too, a balanced tank is used; however, in this circuit the inductance is fixed and tuning is controlled by capacitor C_{43}. The capacitance of C_{43} should be equal to the 5763 output capacitance. In practice, however, the coil is adjusted for a frequency as close to the center of the band as possible, with the capacitor set at approximately 7 $\mu\mu$f. Minor corrections and adjustments are then made with C_{43}. The choke L_{12} permits small unbalances with negligible effect on the output.

Mechanical Considerations

The entire rig is built on an 8 by 4½ by 1½-inch chassis; it is housed in a 5 by 6 by 9-inch box. The photos clearly show the chassis layout. In *Figs.* 2 and 3, the transmitter occupies the right-hand side of the chassis and the receiver is located on the left-hand side. The 6AK5 rf stage is at the rear of the center row of tubes, the 12AT7 oscillator-mixer is the center tube in this row, and the 6C4 detector is in front. The 6AU6 is located to the left of the 6C4 and, from front to rear, the 6AQ5, followed by the voltage regulator. The oscillator tuning capacitor and coil are mounted on a bracket which is mounted between the 6AQ5 and the 12AT7. The leads (thin straps) from this tuned circuit connect to polystyrene feed-through insulators. A ceramic trimmer is mounted directly on the grid feed-through insulator. As a precau-

**Some surplus 6-Mc crystals operate very satisfactorily as 18-Mc overtone units. This is especially true of the air-gap mounted type, the small plated variety usually having poor overtone capabilities.*

tion against self oscillation of the rf amplifier, a thin copper shield is soldered across the 6AK5 socket. This shield minimizes coupling between the input and output circuits. As in the construction of all vhf equipment, short, heavy ground and rf leads should be used.

The transmitter tube lineup starts with the 6AK6 crystal oscillator, located directly behind the front panel. This 6AK6 is followed by the 6AK6 doubler, and the 5763 doubler-final at the rear of the chassis. This layout places the antenna leads for both the transmitter and receiver close together at the rear of the chassis, thereby providing a convenient location for relay RL. The PA tank tuning capacitor and the series-link capacitor are mounted on the rear of the chassis as shown in *Fig. 3,* and are accessible through two holes in the back of the cabinet.

Ventilation and cooling of the unit is provided by rows of ¼-inch holes at the top and bottom of the sides and back of the cabinet. To dress up the appearance of the Twomobile, the cabinet was painted with gray automobile touch-up lacquer, by means of an inexpensive spray gun which operates from the air pressure of a spare tire.

Previous experience with mobile equipment emphasized the importance of making sure that all mounting screws are tight. The constant vibration encountered on the road will loosen mounting hardware in a surprisingly short time. For this reason, it is recommended that lockwashers, "stop nuts," or other means be employed to keep the mounting screws tightened.

Except where specified otherwise, all coils are wound on ¼-inch diameter, paper-base, slug-tuned forms. RCA Type 202L1 TV picture if coils (which are available at many supply houses) were used for this purpose after the original windings were removed. Other types may be substituted, but make certain that the cores are designed for high-frequency use.

Relay RL is shown in the schematic diagram as a three-pole, change-over relay; a four-pole relay is used in the Twomobile. Since relays are in critical supply at this time, it may be difficult to obtain a 6-volt dc, three-pole unit. If the required type is unobtainable, a single-pole and a double-pole combination, or two double-pole relays may be substituted for the three-pole relay. The other alternative is to rewind the coil of one of the many 28-volt relays that are plentiful in surplus. This modification is quite simple; e.g., for a conversion from 28 volts to 6 volts, the procedure consists of unwinding the coil and rewinding the form with wire which is six wire sizes larger.*

Alignment and Tuning†

Alignment of the Twomobile is comparatively simple. A grid-dip oscillator would be invaluable for this purpose but it is not absolutely necessary; the tuned circuits of the Twomobile can be easily adjusted with the aid of a wavemeter, an output indicator such as a crystal-diode, field-strength meter, signal source, and a 60-ma miniature lamp (pink bead) with a single-turn loop.

Receiver. Adjust the second detector to 11 Mc by varying the inductance of L_5 to where a wavemeter, tuned to this frequency and coupled loosely to L_5, pulls the circuit out of regeneration. (The frequency of the second detector may be checked more accurately with a communications receiver tuned to pick up the radiation from the detector.) The frequency of the oscillator should be checked with a wavemeter while trimmer capacitor C_{10} is adjusted. Set C_{10} so that the mid-range setting of the tuning capacitor corresponds to a frequency of 135 Mc. Connect a signal source to the antenna connector and peak the antenna trimmer, C_1, and the grid and plate coils, L_1 and L_2, for maximum output. (Adjust L_1 by squeezing or spreading the coil turns.)

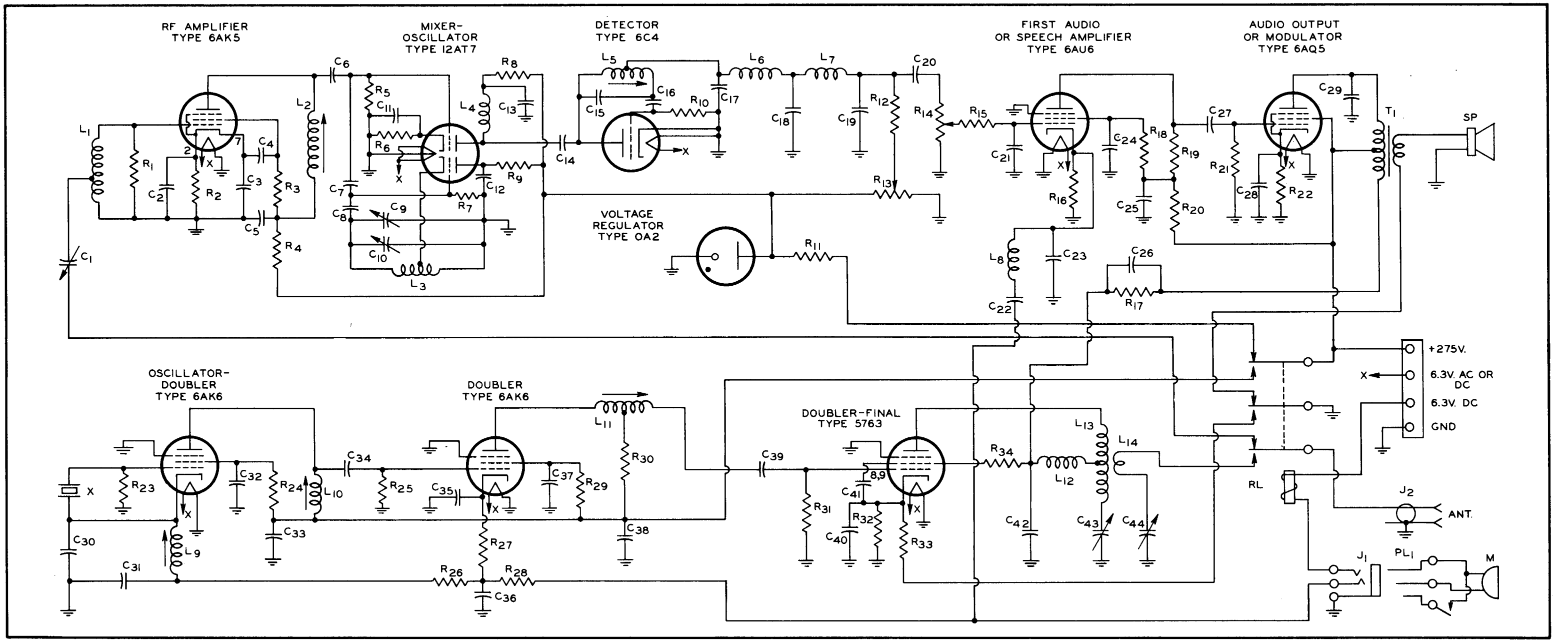
To obtain maximum performance from the receiver, it may be necessary to employ some cut-and-try experimenting with the tap position on L_1, the capacitance of the mixer injector capacitor, C_7, and the quench-frequency network R_{10}—C_{16}.

Transmitter. The first step in the tuning procedure is the adjustment of the oscillator inductor, L_9, to the point where the crystal oscillator starts oscillating. A receiver tuned to 18 Mc may be used as an indicator. Couple a single-turn loop with a 60-ma miniature lamp to L_{10}, the oscillator plate tank, and peak L_{10} for maximum output as indicated by the lamp brightness. Use a wavemeter to make sure that the plate circuit of the oscillator is tuned to 36 Mc rather than to a higher harmonic. Follow this procedure in tuning L_{11}, the doubler plate tank, to 72 Mc. Using the field-strength meter, tune the output tank to resonance by varying capacitor C_{43}, and adjust C_{44}, the output trimmer for maximum output. Alternately readjust C_{43} and C_{44} until the output is peaked as high as possible. Finally, go backward through the alignment procedure and peak each circuit for maximum output.

The transceiver is now ready for operation—happy Twomobiling!

"Converting D-C Relays," by R. B. Tomor, W1PIM, Radio News, *December, 1948.*

†*The antenna should be connected during alignment.*



C_1, C_{10}	4-30 μμf, ceramic trimmer (Erie TS2A, N500).
C_2, C_3, C_4, C_5, C_{11}, C_{12}, C_{13}, C_{21}, C_{23}, C_{31}, C_{32}, C_{33}, C_{35}, C_{37}, C_{38}, C_{40}, C_{41}	1,000 μμf, ceramic (CRL disc Hi-Kap).
C_6, C_8, C_{14}	22μμf, ceramic (CRL tubular Hi-Kap).
C_7	1-in. length of 70-ohm twin lead.
C_9	2-plate, midget variable (Millen 20015, plates removed).
C_{15}	39 μμf, mica (El-Menco CM-15).
C_{16}, C_{34}, C_{39}	56 μμf, mica (El-Menco CM-15).
C_{17}, C_{18}, C_{19}, C_{27}	5,000 μμf, ceramic (CRL disc Hi-Kap).
C_{20}	0.01 μf, paper.
C_{22}, C_{26}	10 μf, electrolytic, 50 wv.
C_{24}	0.05 μf, paper.
C_{25}, C_{28}, C_{36}	Triple-unit electrolytic: C_{25} 10 μf, 350 wv. C_{28} 20 μf, 50 wv. C_{36} 20 μf, 50 wv.
C_{29}	3,000 μμf, ceramic (CRL tubular Hi-Kap).
C_{30}	100 μμf, mica (El-Menco CM-15).
C_{42}	2,000 μμf, mica (El-Menco CM-15).
C_{43}	14 μμf, midget variable (Johnson 15M11).
C_{44}	25 μμf, midget variable (type APC).
J_1	3-circuit microphone jack.
J_2	Coaxial connector, UG-2900.

NOTE
All mica and paper capacitors should have a rating of at least 400 volts.

L_1	4 turns No. 16 enam., 3/8-in. diam., spaced to over-all length of 3/4 in., tapped 1 turn up from ground end.
L_2	3 turns No. 28 d.c.c., spaced to over-all length of 1/2 in.*
L_3	3 turns No. 12 enam., 1/2-in. diam., spaced to over-all length of 1 in., tapped 1 turn from ground end.
L_4, L_6	Choke, 100 μh (National R-33).
L_5	22 turns No. 28 d.c.c., close wound, center tapped.*
L_7	Choke, 80 mh (Meissner 19-686).
L_8, L_{12}	Choke, 144-Mc (Ohmite Z-144).
L_9	7 turns No. 28 d.c.c., close wound.*
L_{10}	14 turns No. 28 d.c.c., close wound.*
L_{11}	10 turns No. 28 d.c.c., close wound, center tapped.*
L_{13}	6 turns No. 16 enam., 1/2-in. diam., spaced to over-all length of 1 1/4 in., center tapped.
L_{14}	1 1/2-turn link, No. 16 enam., interwound in center of L_{13}.
M	Single-button, carbon microphone.
PL_1	3-circuit microphone plug.
RL	3-pole, double-throw, 6-v dc relay (Potter & Brumfield KR-14D).

R_1, R_3, R_7	10,000 ohms.
R_2, R_{30}	220 ohms.
R_4, R_6, R_8, R_9	1,000 ohms.
R_5, R_{18}	1 megohm.
R_{10}	820,000 ohms.
R_{11}	5,000 ohms, 10 watts.
R_{12}, R_{20}	27,000 ohms.
R_{13}	50,000 ohms, potentiometer, 1 watt.
R_{14}	250,000 ohms, potentiometer, audio taper.
R_{15}, R_{16}	2,000 ohms.
R_{17}	1,200 ohms, 1 watt.
R_{19}	390,000 ohms.
R_{21}, R_{32}	470,000 ohms.
R_{22}	470 ohms.
R_{23}, R_{25}, R_{31}	82,000 ohms.
R_{24}, R_{29}	22,000 ohms.
R_{26}, R_{27}	120 ohms.
R_{28}	390 ohms.
R_{33}	68 ohms.
R_{34}	12,000 ohms, 1 watt.
SP	2-in., p-m speaker.
T_1	4-watt output transformer, pp plates to voice coil (Merit A-2900).
X	18-Mc crystal.

NOTE
All resistors 1/2 watt unless specified otherwise.

*Wound on 1/4-in. diam., slug-tuned form (from RCA 202L1 picture if coil).

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MAXIMUM ICAS* RATINGS

	Below 60 Mc	At 150 Mc
CW		
Plate voltage	750	435 volts
Plate current	150	150 ma
Plate input	90	65 watts
Phone		
Plate voltage	600	350 volts
Plate current	125	125 ma
Plate input	67.5	48 watts

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Here's a power tube that will outperform anything in its class. Rated to 175 Mc—only a trifle larger than a 2E26—the new RCA-6146 beam power tube is tailor-made for the amateur 2-meter band.

Rated at a heater voltage of 6.3 volts and current of 1.25 amperes, the RCA-6146 can deliver a CW output (ICAS) of approximately 69 watts at frequencies up to 60 Mc. At 150 Mc, the CW output (ICAS) is approximately 35 watts or better. An RCA-5763 or an RCA-2E26 is an excellent driver for this trim powerhouse.

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Joseph Pastor, Jr., W2KCN
Editor

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HAM TIPS
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Vol. 12, No. 2 July, 1952

Unusual Transmitter for the Novice Features the New RCA-6146

This Clean-Cut Unit Employs Conventional Circuits and a Number of Features Which Will Appeal to the Newly-Licensed, General-Class Operator

By
F. S. Barkalow, * W2BVS

General Description

THE transmitter shown in *Fig. 1* is an rf unit, complete with power supply, for cw operation on 80, 40, and 20 meters. As shown in the schematic diagram *Fig. 6,* the tube line-up starts with a crystal controlled pentode oscillator using a 6V6-GT. This stage is coupled to a 6146 beam-power final amplifier. This transmitter employs a common power supply for both the oscillator and the final, and features regulation of the oscillator plate voltage.

Another feature of general appeal is a tune-operate switch which increases the cathode resistance in the final amplifier during the initial tuning, thereby protecting the tube from accidental overloading. Also of interest is the use of a cathode-current (total tube current) milliammeter in the final; in the key-up position, this meter indicates grid drive directly. Keying is accomplished by means of a keying relay in the B+ lead of the 6146 final. For simplicity and low cost, plug-in coils and a crystal oscillator are employed. Frequency shifting is accomplished by means of crystal switching; however, a co-ax connector is provided for connection to an external VFO.

The power supply shown in *Figures 2, 4, and 6* delivers 600 volts dc, at currents up to 200 milliamperes. A conventional circuit is employed except for the inclusion of a pair of OD3's to regulate the plate voltage for the oscillator tube.

The two voltage-regulator tubes in series with variable resistor R_{13} are

**RCA Tube Dept., Harrison, N. J.*

CQ WN

Every serious-minded, dyed-in-the-wool Novice will profit greatly by reading W2BVS's article. It was written for the Novice by an ex-Novice after much consultation with the many old-timers at RCA.

The rig with the "commercial" appearance shown below is simply the result of applying a Novice's enthusiasm and ingenuity plus the old-timers' advice to a straightforward circuit. This transmitter was designed expressly for the Novice who is even now planning his future ham station. The design satisfies all of the present requirements of a good Novice transmitter, and already incorporates many of those inevitable changes and additions which usually result in the construction of a new rig.

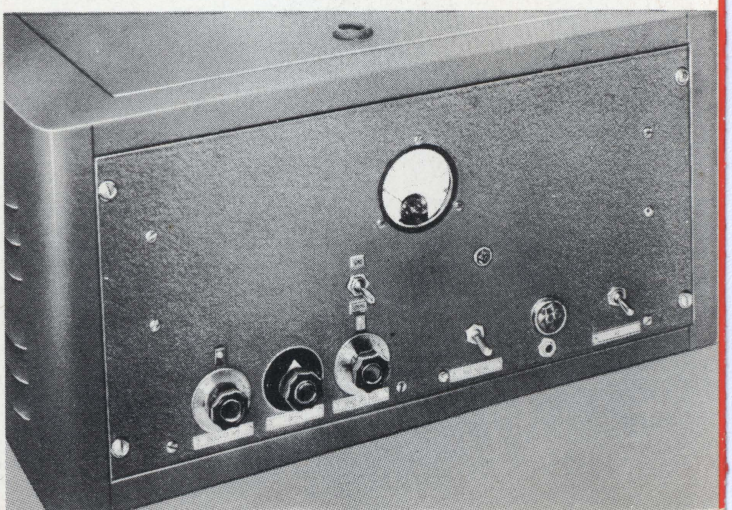


Fig. 1. A well-designed transmitter for the Novice—a good start is always important!

connected from B+ to ground to provide the 300-volt regulated source of plate voltage for the oscillator tube. If an unregulated source is desired, a resistive voltage divider may be substituted for the regulator tubes and resistors R_{12} and R_{13} as shown in the schematic diagram. Note the addition of filter capacitor C_{12} at the junction of R_8 and R_{11}.

Resistor R_{12} discharges filter capacitors C_1 and C_2 when the power is turned off. The jumper in each of the regulator tubes (between pins 3 and 7) is wired in series with the primary of the power transformer so that the transmitter cannot be operated if these tubes are removed. Switch S_4 opens the ground connection to the center-tap of the high-voltage winding during stand-by periods. Indicator lamp PL_2 will glow when S_4 is closed.

Energizing voltage for the keying-relay coil (RL) is obtained from a 6.3-volt winding of the power transformer. This separate winding was used merely because it was available; the relay coil can be connected to the heater winding if a transformer having one heater winding is employed. The relay contacts break the 600-volt dc B+ line to the final amplifier tube.

Capacitor C_{13} and resistors R_9 and R_{10}, mounted at the relay contacts, comprise a key-click filter. A metal cover (not shown in *Fig. 2)* shields the relay and keeps the contacts dust-free. This filtering and shielding plus the use of the external ac line filter (shown in *Fig. 6)* are worthwhile precautions to prevent TVI.

Constructional Details

The rf unit and the power supply are built on separate 3 by 8 by 12-inch chassis. These chassis are attached to a standard 8¾-inch relay-rack panel. A single 3 by 12 by 17-inch chassis can be used instead of the two smaller chassis; however, the adjacent sides of these two chassis form a center partition which enables convenient mounting of the 6146 tank capacitor, shield, and

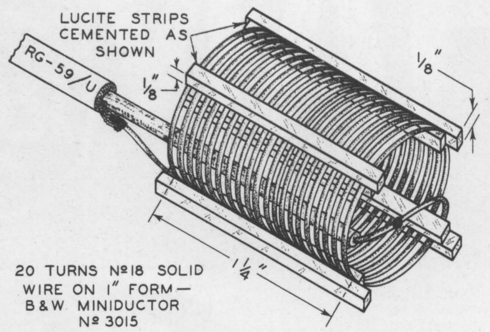


Fig. 3. Recommended method of connecting the coaxial transmission line to the antenna link. The additional Lucite strips keep the link from touching the tank coil.

bleeder resistors R_{12} and R_{13}. This arrangement also enables the builder to construct either one or both of the units, depending upon whether or not a suitable power supply is available.

From left to right on the front panel *(Fig. 1)* are shown the oscillator tank tuning control C_2, the crystal-selector switch S_1, the final amplifier plate tuning capacitor C_7, the plate-voltage switch S_4, power-on indicator lamp PL_1 (under which is located the key jack) and on the extreme right, the power-supply, on-off switch. The tune-operate switch S_2 is located above the final amplifier plate tuning control. To the right of S_2, and above the plate-voltage switch, is located the plate-voltage indicator lamp PL_2. The milliammeter located in the center of the front panel indicates cathode current of the final amplifier.

All of the major components are shown and identified in the photographs; the layout of parts was planned to permit simple wiring with short, direct leads. A common tie point should be used for all grounds in each stage. This practice, although not absolutely necessary for 80-meter operation, is recommended in the event this transmitter will be used for operation at higher frequencies.

The oscillator plate-tank capacitor and the rf amplifier plate-tank capacitor are spaced from the chassis and supported by ceramic insulators because the stator and rotor of each capacitor is above ground potential by the B+ voltage. Fibre shafts and flexible couplings are employed to keep these potentials from existing at the tuning knobs.

The rf amplifier plate-tank circuit is completely shielded from the grid circuit, both above and below the chassis, by two aluminum shields bent as shown in the photographs *Figures 2 and 5.* The base sleeve of the 6146

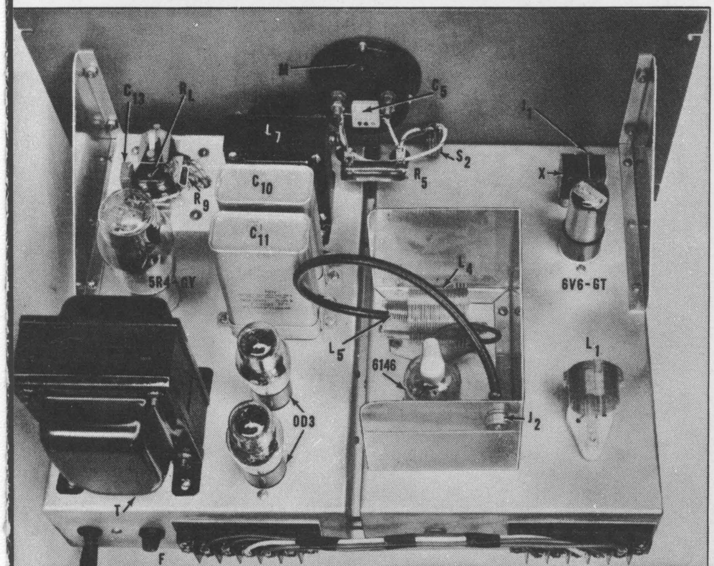
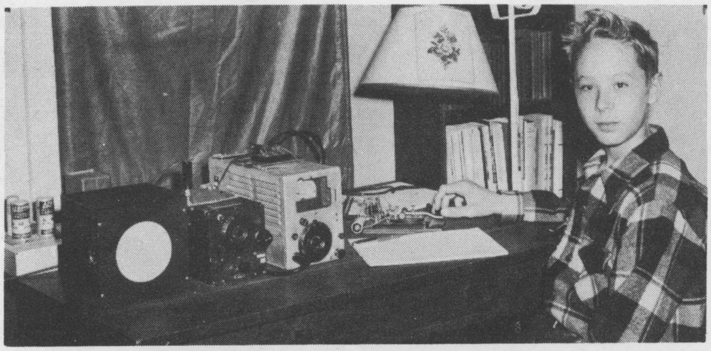


Fig. 2. This layout is a fine example of craftsmanship and simplicity. Although the use of the voltage regulator tubes in the power supply is highly recommended, they may be omitted if the beginner so desires; an alternative voltage divider is described in the text.

Second Novice License in 2nd District Held by Son of RCA's Frank F. Neuner, W2ZPD

A slice of the old ham! We're proud to introduce Frank J. Neuner, WN2IHS, who received his Novice license at the age of 14. He is a sophomore at Bloomfield (N. J.) High School. The transmitter at WN2IHS is a BC-457 (modified to crystal control) running 35 watts input on 3.735 Mc; the receiver is a BC-454. Frank is now studying for the General-Class examination. His dad is a Group Manager in the Product Administration Division, RCA Tube Dept., Harrison, N. J.



shields the input to the tube and isolates it from the output circuit. Pin 8, which is connected to the sleeve, must be grounded. Coupling the antenna to the final amplifier is accomplished by inserting a link L_5, into the cold (B+) end of tank coil L_4. This link is connected by means of a short piece of RG-59/U coaxial cable to the antenna connector J_2 mounted on the shield which surrounds the final amplifier tube and coil.

A piece of ¾-inch Celotex is placed between the relay and the chassis to deaden the sound of the relay armature. A metal cover for the relay should be provided for the reasons given under "General Description." Check the inside dimensions of the cover to make certain that there is sufficient spacing to clear all parts of the relay.

Adjustment and Tuning

Power Supply. Carefully check the power supply to make certain that it has been correctly wired and adjusted *before connecting it to the transmitter.* The only adjustment in the power supply will be the setting of the slider on resistor R_{13}. **(Always remove the line cord from the ac power source before any adjustments are made in the power supply.)** This adjustment can be made as follows: Insert a milliammeter between pin 2 of the lower regulator tube *(Fig. 6)* and ground, and adjust the slider for a current of 40 ma. (Caution should be observed when the adjustable slider on this resistor is moved. Resistors of this type are wound with very fine wire which can be easily damaged by the slider contact. *Before attempting to move the slider from one point to another along the bleeder, loosen the slider set-screw and rotate the slider so that the contact moves on the vitreous enamel coating and not on the wires.* After this adjustment is completed, reconnect pin 2 of the regulator tube to ground. Once the slider is set for this current of 40 ma, the oscillator plate voltage will be regulated at 300 v; this regulation will be maintained provided that the current drawn by the oscillator tube does not exceed 35 ma. Under normal operating conditions, a purple glow is visible in the regulator tubes; however, if the load current exceeds 35 ma, the glow will cease, thereby indicating a loss of regulation (this condition will occur if the 6V6-GT stops oscillating).

Oscillator. Insert the 80-meter coils and a crystal for the 80-meter Novice band. Before applying the power, make certain that the plate-voltage switch, S_4, is opened. Turn on the supply and allow sufficient time for the heaters to warm up. Then apply plate voltage to the oscillator by closing the plate-voltage switch. With the key up, oscillation should take place as capacitor C_2 is varied; oscillation will be evidenced by a small indication on the meter. The meter indicates grid current of the 6146 (approximately 3 ma) when the key is in the up position.* A ¼-watt neon lamp held near the oscillator plate coil will glow as a further indication of oscillation. If the oscillator plate coil is of the type specified and modified as noted in the parts list, oscillation will occur when C_2 is set at approximately half its maximum capacitance.

While capacitor C_2 is varied, note that the grid current of the 6146 rises gradually until a peak is reached and then it cuts off suddenly and oscillation ceases. The correct setting of C_2 is a point just before the peak is reached.

Final. When the tank circuit of an rf amplifier tube is tuned off resonance, the plate current increases. Because the off-resonance plate current of the 6146 will be quite excessive, care must be observed in order to prevent damage to the tube and/or the meter.

To prevent damage to the 6146 and the meter while locating the resonant setting of C_8, a tune-operate switch, S_2, is incorporated in the circuit. In the "TUNING" position of S_2, a fairly high resistance (R_4) is placed in series with the cathode resistor of the 6146 to limit the plate current to a safe value. With S_2 in the "TUNING" position and with the antenna disconnected from link L_5, the tank capacitor should be tuned for resonance.

**The meter indicates 6146 cathode current (total tube current) when the key is pressed.*

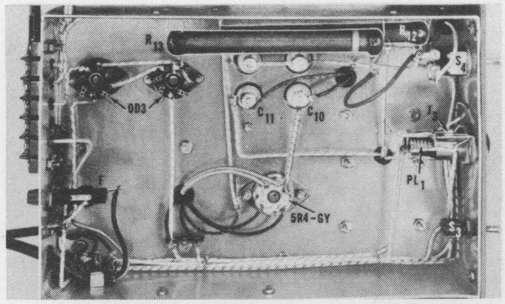


Fig. 4. An example of neat wiring. Note that R_{13} is mounted above R_{12} to permit easy access to the adjustable slider.

After the resonant setting has been found, throw S_2 to the "SEND" position to short out resistor R_4; connect the antenna to the loosely coupled variable link L_5. The tank capacitor C_7 should be readjusted for resonance. Check the 6146 plate current for this amount of antenna loading. The loading can be increased by moving the link further into the tank coil and retuning for resonance. **(Do not attempt to adjust the link when the power is on.)** With 600 volts on the plate of the 6146, the loading can be increased up to a maximum plate current of 150 ma* for an input of 90 watts (for General-Class operation).

Since the meter indicates cathode current, it is necessary to subtract the control- and screen-grid currents from the meter reading to obtain the plate-current value for a determination of the power input to the 6146 (At the maximum input of 90 watts, the screen current will be approximately 15 ma with a recommended grid-No. 1 current of 3 ma.).

Operation on 40 meters is possible with either a 40- or 80-meter crystal and a 40-meter oscillator tank coil. If an 80-meter crystal is used, the 6V6-GT functions as an oscillator-doubler. Similarly, 20-meter excitation for the 6146 is obtained by using a 40-meter crystal and tuning the plate circuit of the "oscillator" to 20 meters. The 6146 operates straight through on 80, 40, and 20.

It is desirable to have some means for checking the oscillator and final tank circuits to make certain that they are tuned to the desired bands rather than to harmonics, particularly if a substitution of components has been made for those specified in the parts list. Either an absorption-type wavemeter or a grid-dip meter may be used for this purpose. It is well for the Novice to remember that crystal control does not insure the operator against outside-the-band operation. After making certain that C_2-L_1 and C_8-L_4 are tuned to the desired bands, a wavemeter or a receiver should be used to check the output of the transmitter to determine whether harmonics are present.

**ICAS, class C telegraphy.*

TVI

This transmitter was operated on 80 meters with a half-wave doublet antenna fed with RG-59/U coaxial cable.

Operation of the transmitter without the cabinet resulted in serious TVI (on all channels) on a set of 1947 vintage which was located 300 feet from the transmitter. TVI was also encountered in the writer's TV set (on all channels) which was located approximately 30 feet from the transmitter; the spacing between the TV antenna and the transmitting antenna is approximately 30 feet.

Placing the transmitter in an unaltered metal cabinet eliminated both of these cases of TVI completely. The closest neighbor (100 ft away) reports that he hasn't any TVI. As a check, the writer's TV set was operated at a distance of four feet from the transmitter (with an indoor folded dipole); it was impossible to find any trace of TVI. Additional TVI precautions (such as the use of lead filters, a low-pass filter, cabinet alterations, etc.) may be necessary when this transmitter is operated on 40 or 20 meters. The Summer, 1951 issue of HAM TIPS contains an excellent article (including many references) on the elimination of TVI.

Key clicks which were heard in both an ac/dc receiver and a phono player were eliminated by building a filter (see *Fig. 6)* and inserting it between the power-supply line cord and the ac outlet.

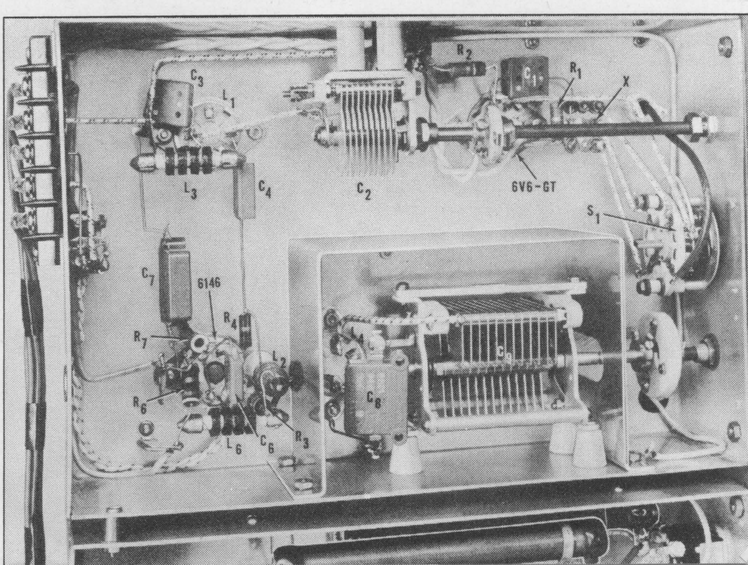


Fig. 5. A close-up of the rf chassis. Note that coupling capacitor C_4 is mounted with its edge toward the chassis to minimize stray capacitance, thereby preventing a waste of driving power. The twisted leads running along the bends of the chassis supply heater voltage to the tubes.

On-the-Air Performance

During a one-month period of operation on 80 meters, 30 states were worked as well as Canada. Very fb reports were received on the quality of the note. The results were most gratifying and proved the RCA-6146 to be a tube with a bright future.

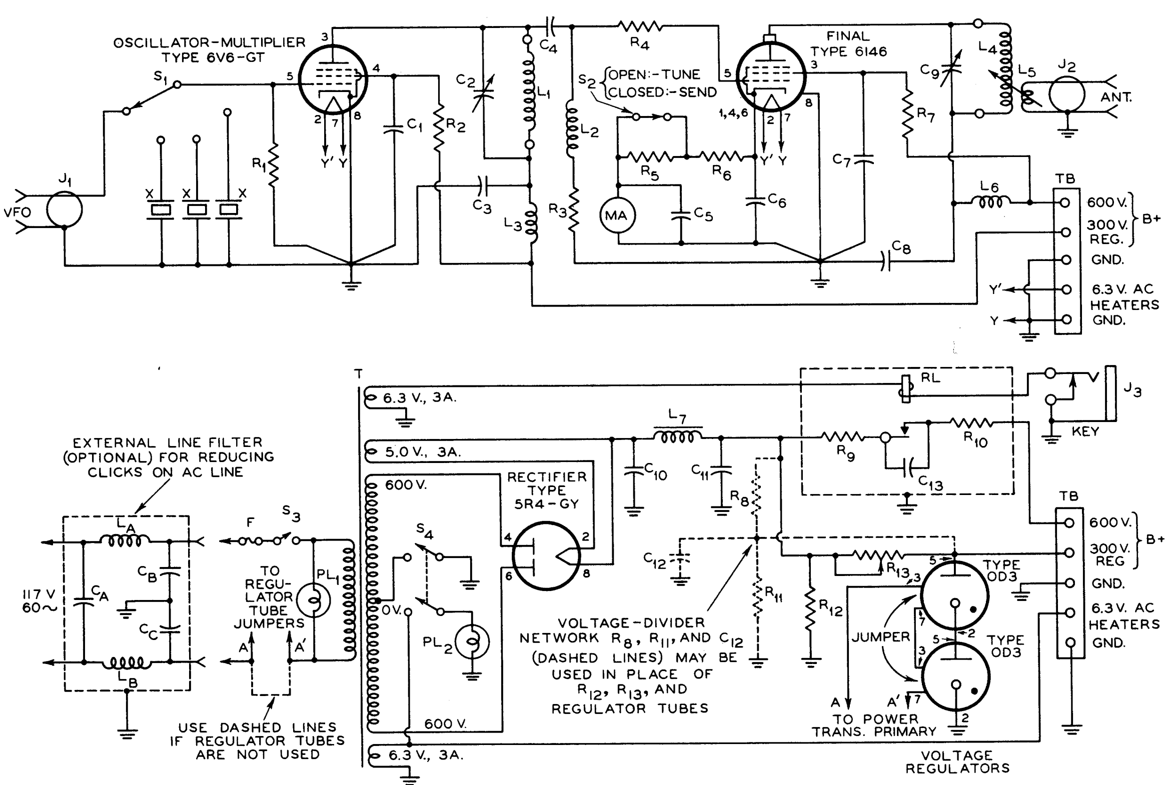


Fig. 6. Schematic diagram of the transmitter and power supply.

Transmitter

C_1, C_3, C_5, C_6	0.005 μf, mica, 500 v.
C_2	100 $\mu\mu f$, variable (National TMS100).
C_4	50 $\mu\mu f$, mica, 500 v.
C_7, C_8	0.005 μf, mica, 1,500 v.
C_9	150 $\mu\mu f$, variable (National TMK150).
J_1, J_2	Amphenol 75PC1M.
L_1	B & W MEL, 16 turns removed (80 meters)—see text.
L_2, L_3, L_6	2.5 mh (National R100).
L_4	B & W 80 JEL, 8 turns removed. B & W 40 JEL B & W 20 JEL
L_5	20 turns B & W Miniductor 3015.
M	0-200 ma type 301.
R_1, R_2	50,000 ohms, 1 watt.
R_3	47,000 ohms, 2 watts.
R_4	50 ohms, 1 watt.
R_5	750 ohms, 25 watts (Ohmite 0203).
R_6	50 ohms, 2 watts.
R_7	25,000 ohms, 10 watts (Ohmite Brown Devil).
S_1	Mallory "Hamband" switch.
S_2	SPST, toggle, 125 v, 3 amp.
TB	Jones 5-142Y.
X	Crystal, 3.5 or 7 Mc (see text).

Power Supply

C_{10}, C_{11}	4 μf, oil-filled, 1000 wv (Cornell-Dubilier TJU 10040J).
C_{12}*	8 μf, electrolytic, 600 wv.
C_{13}	0.002 μf, mica 1,500 v.
F	3AG 3 amp (for Littlefuse 342001 holder).
J_3	Closed-circuit type (Mallory A2).
L_7	6 h, 200 ma (Thordarson 20C55).
PL_1	125 v, 6 watts.
PL_2	6.3 v.
R_8*	7,500 ohms, 50 watts (Ohmite 0579).
R_9, R_{10}	50 ohms, 1 watt.
R_{11}*	30,000 ohms, 50 watts (Ohmite 0586).
R_{12}	25,000 ohms, 75 watts (Ohmite 0788).
R_{13}	10,000 ohms, adjustable, 75 watts (Ohmite 0783).
RL	6.3 v (Guardian K320).
S_3	SPST, toggle, 125 v, 3.5 amp.
S_4	DPST, toggle, 125 v, 3.5 amp.
T	600-0-600 v, 200 ma; 5 v, 3 amp; 6.3 v, 3 amp; 6.3 v, 3 amp (Stancor type PC8414).
TB	Jones 5-142Y

*Components for alternative voltage divider.

For civil defense or mobile transmitters

your best bet is **beam power**

These rugged, RCA-developed *VHF* beam power tubes have no equals for mobile or emergency rigs. Because of their high efficiency and high power gain, they require less drive and deliver more output at lower plate voltage, than any other similar types of comparable price range. Translate these advantages into practical results and they spell *power economy, more watts per dollar, and compact transmitter design.*

The RCA 5763 *miniature* beam power tube is ideal as the final in a low-power rig, as a frequency multiplier, and as the driver for an RCA-2E26 or 6146. As a final it will handle 17 watts input on cw and 15 watts on phone with a simple 300-volt power supply.

The RCA-2E26 beam power tube will handle a full 40 watts input on cw and 27 watts on phone . . . and can be modulated with a 6N7 Class B operated. It also makes an excellent driver for the new RCA-6146.

The RCA-6146—the tube that's tailor-made for "2"—will take 64 watts on cw and 48 watts on phone at 150 Mc . . . yet it's only a trifle larger than a 2E26!

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HAM TIPS

A PUBLICATION OF THE TUBE DEPARTMENT · RCA · HARRISON, N. J.

Vol. 12, No. 3 November, 1952

An All-Band Antenna and Coupler

By

J. H. Owens,*W2FTW

DO you want to work 75 or 80, 40, 20, and 10 meters with a single sky-wire? Is your space limited, and cost a factor? If so, here is a way to do it—with actual performance advantages over simple dipoles for each band.

The general idea is to take a 75/80-meter dipole and fold it so that desirable standing-wave voltage and current relationships are maintained on the higher-frequency, harmonically-related bands.

Fig. 1 shows the configuration and dimensions of the antenna. It is simply a 75/80-meter dipole with the ends folded back and over the center portion. It must radiate because it is resonant and unshielded. Since it radiates the energy that is fed to it, the only other major consideration is directivity. In this respect, it is less directional than a straight-line 75/80-meter dipole, and the angle of radiation is somewhat higher. This latter characteristic is desirable if you want to join the Rag Chewers on 75 and make regular contacts with stations inside a two- or three-hundred mile radius.

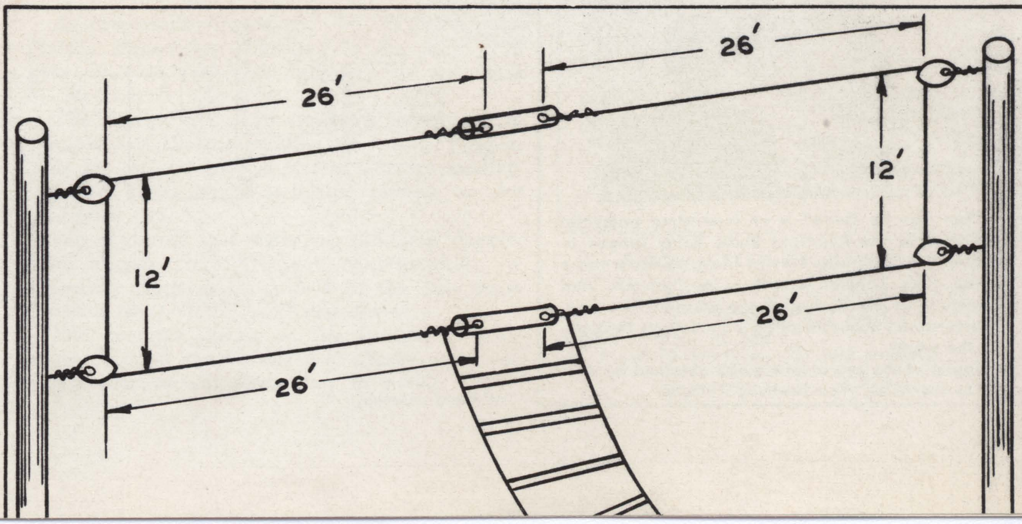
Fig. 2a shows maximum voltage points when the antenna is used on 40 meters. The antenna consists of two half-wave dipoles, partially folded, vertically polarized, and 180 degrees out of phase. The angle of radiation is somewhat lower than that of a dipole of equivalent height, and the directivity pattern is slightly end-fire.

Voltage points for 20-meter operation are shown in *Fig. 2b.* Here, the antenna approximates a beam because it provides two half-waves in phase on one side, which are in phase with the two in-phase half-waves on the other side. Best DX is obtained in the broadside direction in which the angle of radiation is low, but there are some minor lobes which provide satisfactory operation in all directions during periods of short skip.

Similarly, *Fig. 2c.* shows voltage points for ten meters. This arrangement provides two full-waves in phase on one side, but 180 degrees out of phase with the two in-phase full-waves on the other side. The field pattern is quite complex, and for all practical purposes may be considered omnidirectional. The pattern con-

* *RCA Tube Dept., Harrison, N. J.*

Fig. 1. Layout and dimensions of the all-band antenna.



tains major lobes each having a low angle of radiation—a highly desirable feature for 10-meter DX.

Antenna Coupler

Like most all-band antennas, this one should be fed with tuned open-wire feeders employing four- or six-inch spreaders. An antenna coupler is employed to provide an impedance transformation, a means for tuning the antenna and feeders to resonance, and attenuation of harmonics. Any of the well-known antenna couplers will perform these functions conveniently and economically.

The coupler shown in *Fig. 3* is electrically the well-known, Pi-section filter with link coupling. It consists of two variable capacitors and a swinging-link, push-pull plate tank coil—the one for the next lower frequency band than the band to which the final amplifier is tuned. For instance, if the transmitter is being operated on 20 meters, the 40-meter coil would be used in the coupler.

Capacitors C_1 and C_2 can be of the split-stator type if the capacitance per section is double the values shown. Single-stator capacitors have been used with excellent results. The voltage rating of C_1 should be equal to that of the tank capacitor in the final amplifier, but C_2 need have a voltage rating of only half as much. Depending upon the length of the feeders, optimum loading may be obtained by connecting them across C_1 or C_2.

Tuning

In operation, the coupler is first tuned to resonance as indicated by an increase in the plate current of the final amplifier. The ratio of the capacitance of C_1 to C_2 is then varied to provide maximum loading of the final amplifier, and the swinging links are adjusted for desired plate current. The tuning procedure is the same for all bands.

Good results were obtained on all bands from 80 to 10 meters with an antenna less than 60 feet long and with its upper radiator only 20 feet above ground.

Do You Know of Any Would-Be Hams?

"You Can Be There" is an interesting pamphlet published by the American Radio Relay League to promote interest in the Novice Class, amateur-radio license. This booklet describes the romance and adventure to be derived from personal two-way, amateur-radio communication with stations throughout the world.

Copies of the pamphlet may be obtained by writing to the ARRL, West Hartford 7, Conn.

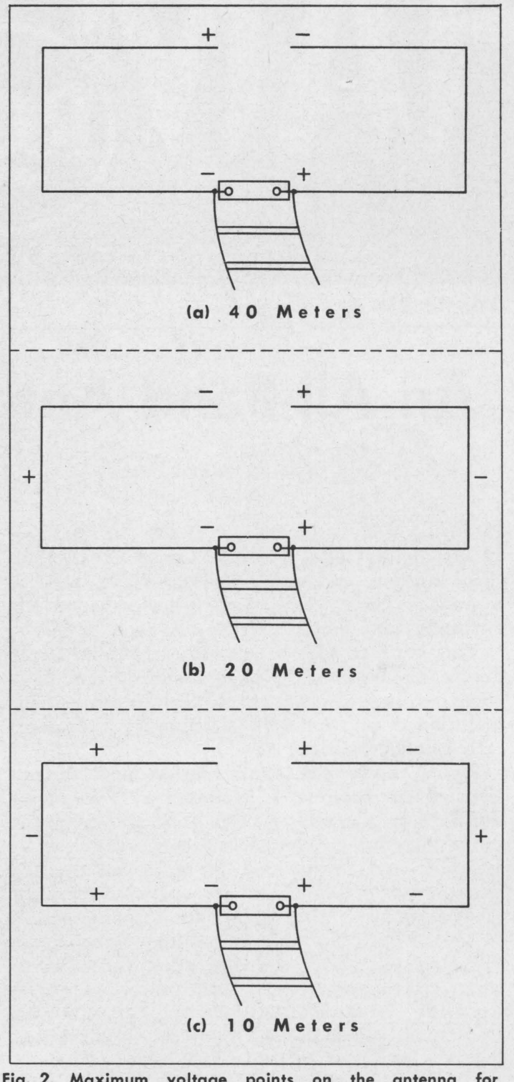


Fig. 2. Maximum voltage points on the antenna for 40-, 20-, and 10-meter operation.

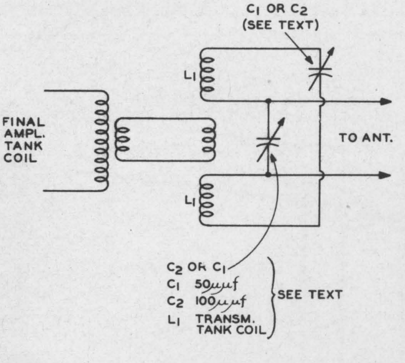


Fig. 3. Circuit of the antenna coupler used with the all-band antenna.

A New Superhet S-Meter Circuit

Combining the Second-Detector, AVC, Automatic Noise Limiter, First-Audio Stage, with a Bridge-Type Signal-Strength Meter

By
J. H. Owens, W2FTW

THIS article is another proof of the adage, "Necessity is the mother of invention." The equipment with which the author had to cope was a prewar "home-brew" receiver which performed better than many commercially-built receivers, but lacked such refinements as a signal-strength meter and an effective noise limiter. Although ways and means of adding these refinements are revealed in various publications, a new method had to be devised because the lack of chassis space prohibited the use of additional tubes.

It was indeed a difficult problem, but its eventual solution was accomplished by the use of well-known circuitry, two tubes, a 0-1 milliammeter, and relatively few components in a novel arrangement. The novelty lies in a unique circuit which takes full advantage of the many possible circuit arrangements for the multi-section tubes that were selected to replace those in the original complement. The circuit is shown in *Fig. 1.*

Second Detector and AVC Circuit

The second detector is the usual half-wave rectifier (one half of a 6H6) connected to the secondary of the last if transformer. The load network consists of R_2 and R_3, bypassed at the intermediate frequency by capacitors C_1 and C_2. AVC bias voltage is taken from the diode-load network and fed to the avc filter through R_1. If the receiver uses both sharp-cutoff and remote-cutoff tubes in the rf or if amplifiers, it may be desirable to supply two or more levels of avc bias.

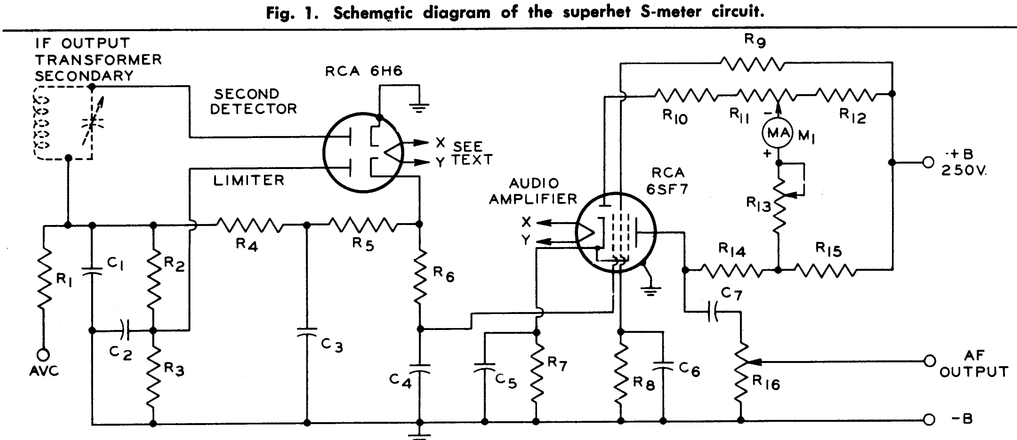
Tubes having a remote-cutoff characteristic should be biased through R_1 from the top of the network; tubes having a sharp-cutoff characteristic should be fed through another 2.2-megohm resistor from the center or other point on the network obtained by substituting two series-connected resistors in place of either R_2 or R_3. The rf amplifier tubes should be fed with only enough avc bias to prevent strong signals from overloading the if amplifier, because high gain in the rf stage is conducive to the best signal-to-noise ratio.

Automatic Noise Limiter

The popular "series-valve" circuit was selected for the automatic noise limiter because of its superior effectiveness, and also because it generates less of the raspy type of audio distortion so common to the "shunt-valve" circuits. The network is composed of the other diode section of the 6H6 together with R_4, R_5, C_3 and the diode-load network. A full explanation of the operation of this circuit can be found in the ARRL Handbook.

The only disadvantage of the series-valve limiter is a possibility of hum pickup. Capacitive coupling and ohmic leakage between the diode heater and its cathode can produce hum because the cathode is in a very-high-impedance,

Fig. 1. Schematic diagram of the superhet S-meter circuit.



Parts List

- C_1, C_2 500 $\mu\mu f$, mica.
- C_3 0.05 μf, paper, 400 v.
- C_4 100 $\mu\mu f$, mica.
- C_5 10 μf, electrolytic, 10 v.
- C_6 0.05 μf, paper, 400 v.
- C_7 0.05 μf, paper, 600 v.
- M_1 0-1 milliammeter.
- R_1 2.2 megohms.
- R_2, R_3 270,000 ohms (See text).
- R_4, R_5 1 megohm.
- R_6 100,000 ohms.
- R_7 150 ohms.
- R_8 86,000 ohms (See text).
- R_9 100,000 or 180,000 ohms (See text).
- R_{10} 68,000 ohms.
- R_{11}, R_{13} 500 ohms, w. w. potentiometer.
- R_{12} 330 ohms.
- R_{14} 47,000 ohms.
- R_{15} 560 ohms.
- R_{16} 1 megohm, potentiometer, audio taper.

NOTE
(All resistors ½ watt)

unbypassed circuit. Hum pickup can be avoided by employing a power transformer having a center-tapped and grounded heater winding. Another alternative is the use of a germanium rectifier; however, the conduction of this device in the reverse direction does not cut off completely—a characteristic which would lower its efficiency as a limiter.

In the author's receiver, one side of the heater-transformer winding is grounded; therefore, an RCA 6H6 was chosen for the limiter rectifier because its internal design is such that grounding either side of the heater transformer winding is just as effective as grounding a center-tap in keeping hum at a minimum. Because there are two 3.15-volt, series-connected heaters in the 6H6, the ac voltage difference between heater and cathode is reduced by 50 per cent as compared to that of many 6.3-volt, heater-cathode tubes. Furthermore, the RCA 6H6 employs double-helically wound heaters which make the tube inherently less susceptible to hum than a tube having a folded heater. The only precaution to be observed in grounding one side of the heater-transformer winding is the requirement that the limiter circuit employ the diode having the grounded heater. For example, if heater pin 2 is grounded, the diode connected to pins 3 and 4 should be used as the limiter; if heater pin 7 is grounded, then the diode connected to pins 5 and 8 should be used. The other diode section is then used as the detector. If these precautions are followed, no perceptible hum should be encountered.

Audio Amplifier

The audio amplifier is "diode-biased" for two reasons. First, this system keeps the ac/dc impedance ratio of the diode load near unity, a requisite for handling, with low distortion, signals having a high percentage of modulation. Secondly, this system provides a source of B+ voltage which varies in proportion to the input-signal level—a requisite for the S-meter circuit. Because the tube grid has to handle the avc voltage plus audio modulation, a low-mu or remote-cutoff characteristic is also required; otherwise, strong signals would cut off the plate current completely. The 6SF7 was chosen for this stage because of its large-signal-handling ability, plus the availability of a diode section which is used in the S-meter circuit. Note that the control-grid is fed through an RC network (R_6-C_4) which de-emphasizes frequencies above approximately 5 Kc.

The 6SF7 is shown in the circuit with its screen-grid voltage taken from a bleeder network. This connection should be used if the receiver if amplifier uses only semi-remote-cutoff tubes (such as the 6SG7, 6BA6, or 6BJ6) and if the avc bias voltage is taken from the top of the diode-load network. If remote-cutoff tubes are used (such as the 6SK7, 6BD6, or 6SS7) in the if amplifier, the circuit should be modified so the 6SF7 acts like a triode insofar as avc signal bias is concerned.

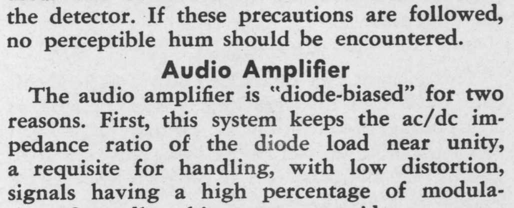


Fig. 2. Scale for the S-meter. The lower half is divided into nine equal divisions, and the upper half into four equal divisions (representing 10-db steps over S-9).

This modification can be made by removing bleeder resistor R_8 and changing the value of dropping resistor R_9 to 180,000 ohms. The screen-grid voltage will then swing up and down with changes in signal level, and the cutoff characteristic of the tube will be greatly extended. With this circuit arrangement, the 6SF7 functions as a triode insofar as avc bias is concerned, but retains the high gain of a pentode insofar as audio is concerned. In both cases, a small amount of cathode-resistor bias is used to minimize the effects of contact potential, a variable factor which might upset normal operation of the circuit.

The output-circuit constants, coupling capacitor C_7 and volume control R_{16}, were chosen especially to feed the grid of a power-output tube. A pair of crystal phones will work well if it is connected between the arm of the volume control and ground. A modification can be made for efficient operation of magnetic-type phones by changing the volume control to a 100,000-ohm unit and adding a matching transformer with its primary connected between the volume-control arm and ground, and the phones connected across its secondary.

S-Meter Circuit

In the S-meter circuit, a novel adaptation of an electronic-bridge circuit is employed to obtain a difference in voltage between two

MEET THE AUTHOR
J. H. Owens, W2FTW

W2FTW since 1946, ex-W3ASZ since 1932.

Home QTH: Merchantville, N. J.

Active on: 75- and 10-meter phone.

Rigs: 100 watts to an 829-B on 75, and 15 watts to a 2E26 on 10.

XYL: Marty.

Harmonics: James, Constance, and Susan.

Started career as a commercial radio operator. Joined RCA Photophone, Inc. in 1930. Transferred to Commercial Sound Div. of RCA during World War II. Joined Renewal Sales Section of the Tube Dept. in 1946. First post-war editor of HAM TIPS. Now Manager of Test and Measuring Equipment Sales.

points in a divider network. The 6SF7 plate and diode function as two arms of the bridge circuit so that the voltages across the bridge terminals depend upon the flow of electrons in a single tube. This arrangement prevents violent deflection of the meter needle when the receiver is first turned on because current starts to flow in each section quite uniformly as the cathode warms up.

This circuit has the desirable feature of up-scale meter deflection for an increase in strength of the received signal. Zero-adjustment is obtained by means of potentiometer R_{11}; this control locates a voltage point on the diode arm which is equal to the voltage at the junction of R_{14} and R_{15} (in the plate-circuit arm) during the absence of signal. When a station is tuned in, the detector develops a negative bias which is applied to the grid of the 6SF7 and, in turn, reduces the dc plate current without affecting the diode current. This reduction in plate current produces an increase in voltage at the positive meter terminal; the voltage at the negative meter terminal remains fairly constant. Thus, the meter is deflected by the current that flows as a result of the voltage difference across its terminals.

Depending upon the gain and the cutoff characteristics of the rf and if tubes used in the receiver, some minor adjustment of the bridge-circuit constants may be necessary in addition to the 6SF7 screen-grid circuit changes previously mentioned. High receiver gain and remote-cutoff tubes will act together to develop rather high avc bias which in turn causes wide-scale deflection with fairly weak signals. Conversely, low receiver gain and sharp-cutoff tubes can develop only a small amount of avc bias even when strong signals are received. Potentiometer R_{13} is a fine-adjustment control for setting the meter to S-9 for a signal that is just strong enough to quiet all of the receiver background noise.

No difficulty should be experienced if the screen-grid circuit of the 6SF7 is set properly so that its cutoff characteristic matches the cutoff characteristics of the tubes in the if amplifier, and if the proper avc bias on the diode-load net-work is selected.

Calibration of the S-meter scale is somewhat academic at best, inasmuch as the S-meter readings for most receivers are a function of receiver sensitivity (which varies with frequency) as well as with the level of the signal on the antenna-input terminals. In this circuit, meter deflection is quite logarithmic, thereby allowing uniform spacing of the scale divisions to indicate power levels in a db ratio. A satisfactory scale is shown in *Fig. 2.*

Adjustment

If a 22.5-volt "B" battery (such as the RCA VS102) is available, it will be found very useful in the adjustment of R_{13}. Connect a 50,000-ohm potentiometer across the battery terminals; then connect the positive terminal to ground. Next, connect the potentiometer arm to R_1 at the point marked "AVC." With the receiver rf gain control set at maximum, rotate the arm to the point where the receiver background noise disappears. The voltage on the arm of the potentiometer is now the same as the avc voltage that would be developed by an S-9 signal. Disconnect the arm of the battery potentiometer from R_1; connect it directly to the grid of the 6SF7, and adjust R_{13} so that the meter indicates S-9. This method is more convenient than listening for a signal of exactly S-9 strength.

Conclusion

This circuit was developed for a home-built communications receiver and is not intended as a suggested modification for commercially-built receivers. It is offered to the radio amateur who would like to further refine his own home-brew superhet.

It performs excellently, and the audio quality is good enough so that means for switching the limiter diode in and out of the circuit are not required.

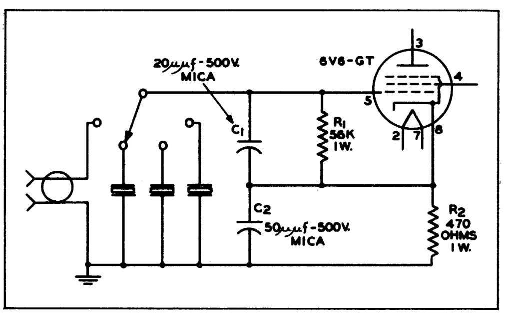
OMISSIONS
(Novice-Transmitter Article)

As originally conceived by W2BVS, the Novice transmitter described in the July 1952 issue of HAM TIPS was designed for operation on 80 meters.

The design was later changed to appeal to the General-Class operator by using plug-in coils for 80, 40, and 20 meters, and by modifying the basic crystal-oscillator circuit to the grid-plate type.

We neglected to inform our drafting department of the circuit changes; consequently, the schematic diagram on page 5 of the July issue contains the original oscillator circuit.

The changes shown in the following schematic diagram are necessary to obtain harmonic output from the oscillator.



Additions to Original Parts List

L_1 B & W 40M "Baby," 8 turns removed.
B & W 20M "Baby," 6 turns removed.

Optional Line Filter

C_A, C_B, C_C 0.01, μf, 600 v.

L_A, L_B 35 turns No. 12 solid enameled wire on a ½-in. diam. fibre (or wooden dowel) form. Wound to a length of 2½ inches.

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	RCA Type Number	RF Service: VFO	RF Service: Xtal OSC	RF Service: Frequency Multiplier	RF Service: Buffer	RF Service: Final	AF Service: Voltage Amplifier	AF Service: Driver	AF Service: Modulator
Octal-Base Types	6AG7	6AG7	6AG7	6AG7	6AG7	6AG7			
	6F6		6F6	6F6	6F6	6F6			6F6
	6J5						6J5	6J5	
	6J7						6J7		
	6L6		6L6	6L6	6L6	6L6		*6L6	6L6
	6N7			6N7					6N7
	6SJ7						6SJ7		
	6SL7-GT							6SL7-GT	
	6SN7-GT						6SN7-GT	6SN7-GT	
	6V6-GT		6V6-GT	6V6-GT	6V6-GT	6V6-GT			6V6-GT
Miniature Types	†5879						5879		
	6AF4	6AF4							
	6AK6	6AK6	6AK6	6AK6	6AK6				
	6AQ5								6AQ5
	6C4	6C4	6C4	6C4			6C4	6C4	
	6J6	6J6	6J6	6J6	6J6	6J6			
	12AX7						12AX7		

*Triode Connected †Special Type

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. . . for low-power-level planning

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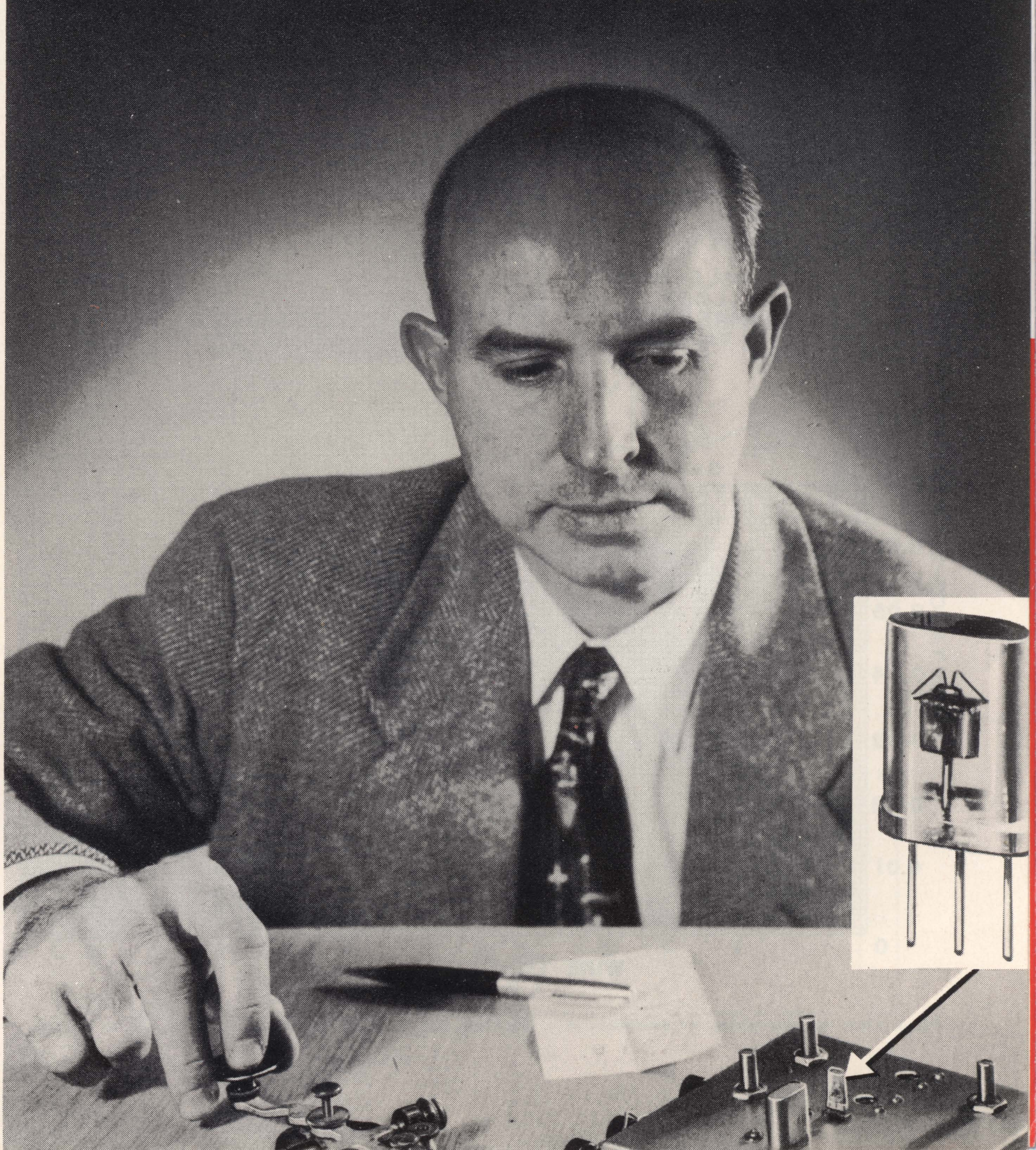
Volume 13, No. 1 January - March, 1953



GEORGE M. ROSE, K2AH, AND HIS HISTORY-MAKING, 146-MC TRANSISTOR TRANSMITTER (See page 3 for story.)

Construction of Inductors for TVI Filters

By
Mack Seybold,* W2RYI

Many of the published articles on the construction of low-pass filters include complete instructions for winding the inductors required for the filter sections. If the author's work is duplicated, and if the directions for winding the coils are followed implicitly, no difficulty will be encountered in building and adjusting the filter. However, the average amateur may experience considerable difficulty if he chooses to modify the original design to suit his particular needs; he may be handicapped by lack of references on the construction of coils which will fulfill given requirements of inductance and Q.

*Tube Dept., Radio Corp. of America, Harrison, N. J.

This article supplies easy-to-follow instructions for winding inductors to given inductance specifications, and describes methods for checking inductance with an accuracy adequate to meet the requirements for practical TVI filters.

Construction

A single-turn flat loop as shown in *Fig. 1* is satisfactory for an inductance of 0.03 to 0.1 µh. For inductances greater than 0.1 µh, the inductor may be wound as a conventional coil having several turns, as shown in *Fig. 2*, in order to conserve space and to maintain a reasonable Q.

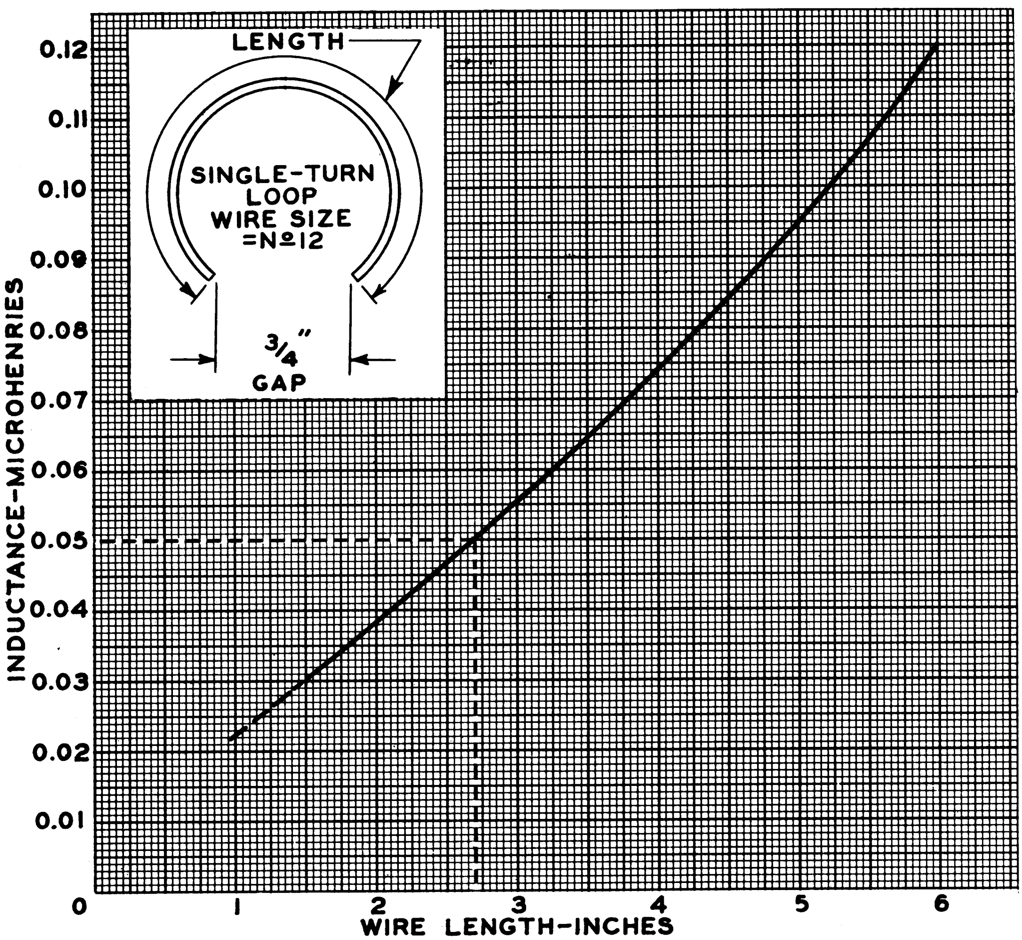


Fig. 1. Curve for determining the dimensions of a single-turn, flat loop (for inductance values of 0.03 to 0.1 µh).

COVER PHOTO

History in the making! George M. Rose (K2AH), Manager of the RCA Tube Department's Advanced Development Group, is shown keying a 146-Mc transistor transmitter. We believe this to be the first use of a transistor in two-way radio communication.

This preview of "things to come" was made possible by the use of a developmental-type transistor now being studied in the RCA Tube Department's laboratories. With this small experimental battery-operated crystal oscillator, K2AH of Mountain Lakes, N. J. contacted W2KNI, Mountainside, N. J. (16 mi. away), W2DPB, E. Orange, N. J. (16 mi. away), and W2UK, New Brunswick, N. J. (25 mi. away)!

According to George, power input to this tiny rig was 30 milliwatts (10 v at 3 ma). This transmitter, employing a point-contact transistor and a 16-Mc crystal operating on its 9th overtone, is powered by a 22½-volt, hearing-aid battery. The transmitting antenna at K2AH is a 12-element beam and the receiving antennas at W2KNI, W2DPB, and W2UK contain 10, 6, and 40 elements respectively.

RCA transistors are still in the developmental stages but when they become commercially available, you will be so informed by an announcement in HAM TIPS.

Example 1. The dimensions of a 0.05-μh inductor can be found from *Fig. 1.* The dashed lines indicate how the wire length (2.7 inches) can be read from the curve opposite the inductance of 0.05 μh. This length of No. 12 wire, when formed into a single-turn flat loop having a ¾-inch gap between the ends of the wire as shown in *Fig. 1,* will have an inductance of 0.05 μh.

Example 2. If a 0.25-μh inductor is required, the number of turns can be determined from *Fig. 2* as shown by the dashed lines. If 3.4 turns of No. 12 wire are wound with a pitch of eight turns per inch and the diameter of

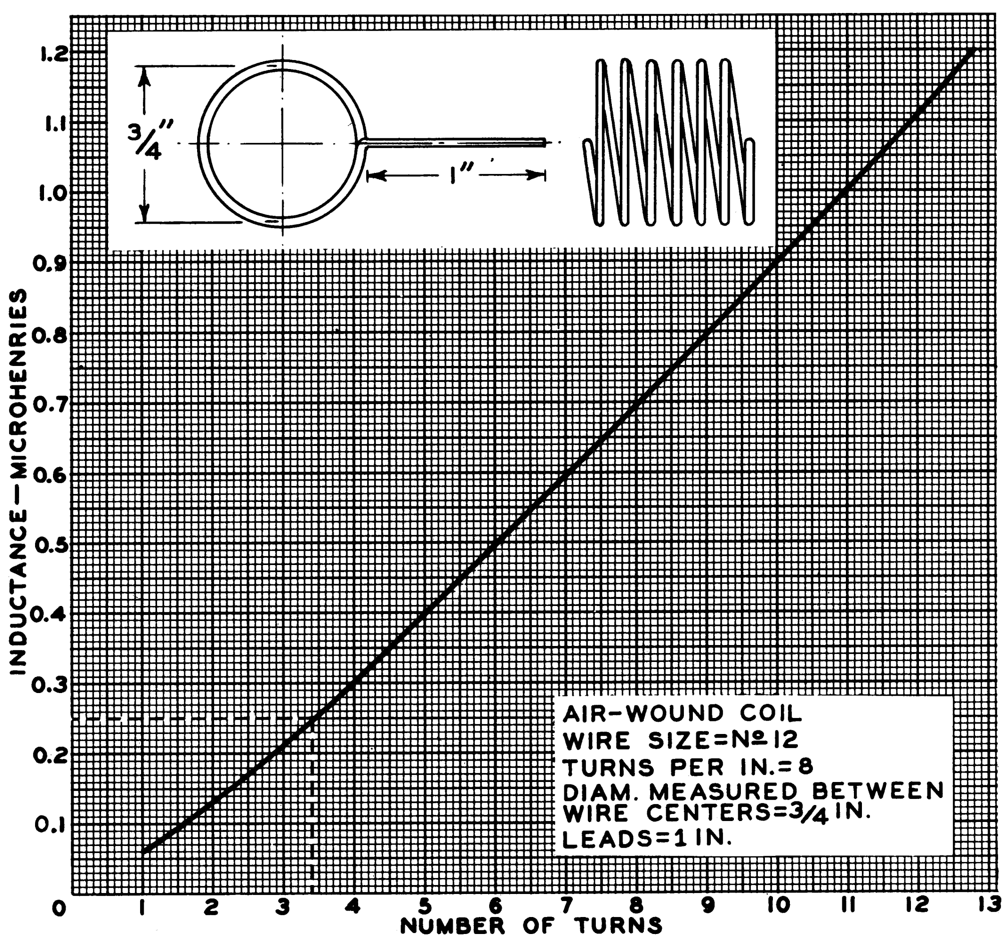


Fig. 2. Curve for determining the number of turns for inductance values greater than 0.1 μh.

the coil is ¾ inch (measured from the center of the wire as shown in *Fig. 2*), the coil will have an inductance of approximately 0.25 μh (including the inductance of the one-inch leads).

Coils wound in accordance with *Figures 1* and *2* are sufficiently accurate for most TVI applications; they may be soldered into a low-pass filter without further adjustment.

If desired, the coil may be wound to other dimensions. The nomograph shown in *Fig. 4* facilitates the selection of suitable values of inductance and capacitance for a circuit resonant at a given frequency. For example, the inductance necessary for resonance at 67.25 Mc with a 20-μμf capacitor can be determined by placing a straight-edge on the nomograph so that it connects the 67.25-Mc point on the frequency scale and the 20-μμf point on the capacitance scale. The intersection of the straight-edge with the inductance scale determines the required inductance value. The inductance, capacitance, and frequency ranges covered in this nomograph are applicable to most low-pass, TVI filter designs.

Measurements

The inductance of the coil may be measured with a Q-meter, or it may be checked in a resonant circuit with a grid-dip meter as shown in *Fig. 3*.

To facilitate measurement of inductance in a resonant circuit with a grid-dip meter, a calibrated variable capacitor should be included in the resonant circuit. Since such a capacitor cannot be found in the average ham shack, a reasonably accurate capacitance standard can be made from a set of six silver-mica capacitors—one each of 5, 10, 20, 40, 70, and 100 μμf (five per cent tolerance). Combinations of these six capacitors will provide a capacitance range of 5 to 150 μμf in 5 μμf steps. Errors can be kept to a minimum by clipping the capacitor leads short and by soldering short connections to the coil being tested. Lumping of capacitance-tolerance error can be minimized by using a single capacitor whenever feasible rather than a combination of capacitors; the use of a single capacitor is practical when the frequency of the signal source can be varied.

The XYL's TV receiver can be used to calibrate the grid-dip oscillator. One or two wide, black, vertical bars will be visible on the kinescope when the grid-dip oscillator frequency is approximately the same as the picture-carrier frequency. When the oscillator frequency approaches the sound-carrier frequency, a T-6 c.w. signal will emanate from the speaker. The distance between the TV antenna transmission line and the grid-dip meter may be five feet or more during this calibration. TV sound– and picture-carrier frequencies for several channels are indicated on the nomograph, *Fig. 4*, for convenient reference when a TV receiver is used for calibrating the grid-dip oscillator.

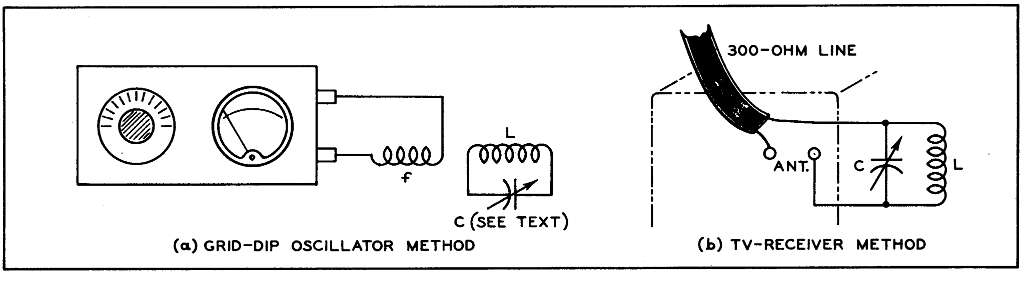
The TV receiver can also be used, alone, as a resonance indicator when a grid-dip meter is not available.* When this method is employed, the parallel resonant circuit containing a known capacitance and an unknown inductance is connected between one side of the 300-ohm transmission line and the TV receiver antenna terminal as shown in *Fig. 3b*. When the inductor and the capacitor are resonant at a picture-carrier frequency, the picture brightness is reduced. When the inductor and capacitor are resonant at a sound-carrier frequency, the volume is reduced.

Two examples are given below to illustrate this method of adjusting coils to specific inductance values. In each case, the coil is connected in parallel with a capacitor (determined from the nomograph for a given TV sound- or picture-carrier frequency) and connected in one side of the transmission line as described above.

Example 1. Using Channel-2 carrier frequencies, adjust a TVI inductor for an inductance of 0.2 μh. (a) From the nomograph, select the value of capacitance necessary for reson-

*"*The Practical Side of Building TVI Filters*," *by J. H. Owens*, "*Radio-Electronics*," *May*, 1952.

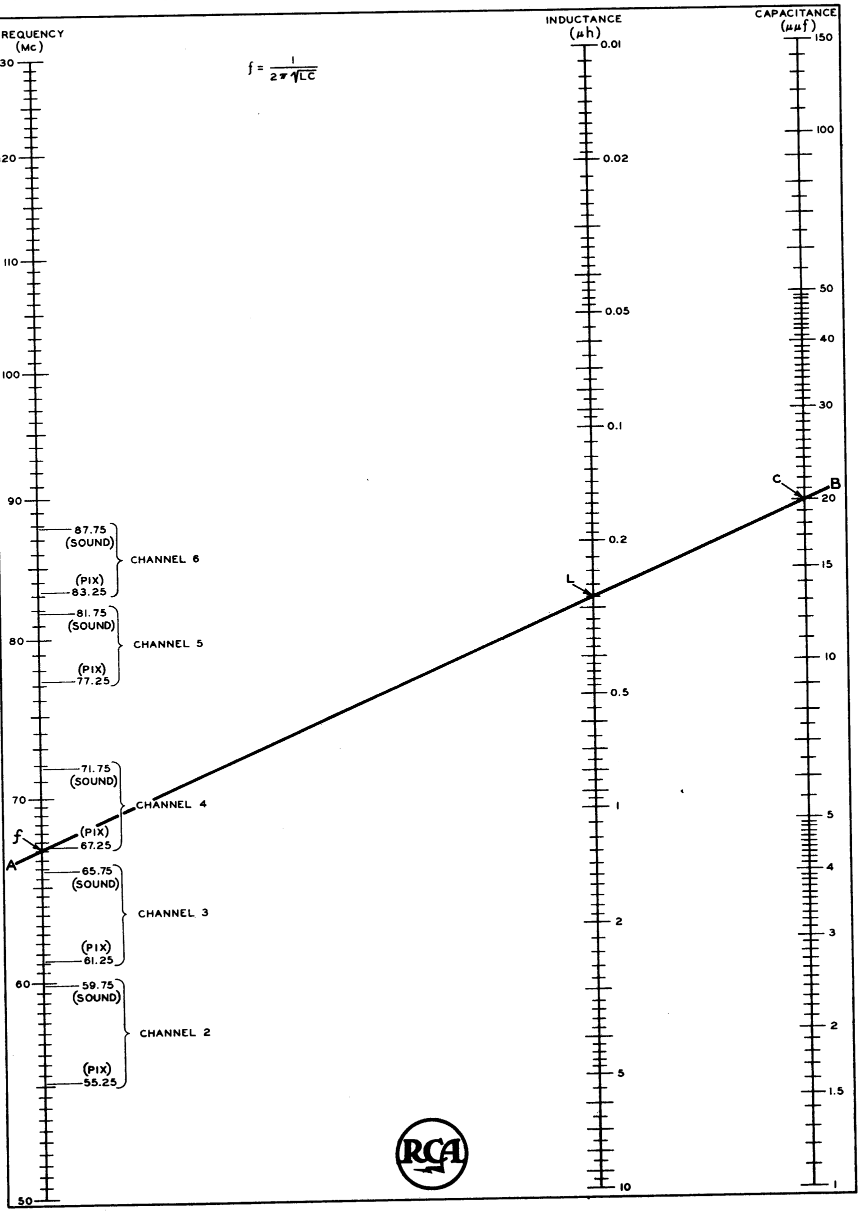
Fig. 3. Two methods of checking inductance by the resonant-circuit method. Capacitor C is a silver-mica type of known capacitance, and L is the unknown inductance.



ance with a 0.2-μh coil at 55.25 or 59.75 megacycles: (C = 41 $\mu\mu$f for the picture-carrier frequency, and 36 $\mu\mu$f for the sound-carrier frequency). (b) Compare these values of capacitance with standard values of silver-mica capacitors and select the closest available capacitor—40 $\mu\mu$f in this case. Connect the coil across the 40-$\mu\mu$f capacitor and prune the coil and vary the spacing between the turns until the Channel-2 picture brightness decreases to a minimum. The inductance of the coil will then be close enough to 0.2 μh for TVI filter applications.

Example 2. Same as *Example 1* except Channel-3 carrier frequency is used as the resonant frequency. (a) From the nomograph, select the value of capacitance necessary for resonance with a 0.2-μh coil at 61.25 or 65.75 megacycles: (C = 35 $\mu\mu$f at the picture-carrier frequency, and 30 $\mu\mu$f at the sound-carrier frequency). (b) Use a capacitance of 30 $\mu\mu$f (20- and 10-$\mu\mu$f capacitors in parallel). Prune the coil and vary the spacing between the turns until the Channel-3 sound drops to a minimum.

Fig. 4. Nomograph for determining any one of the three parameters, inductance, capacitance, or resonant frequency of a parallel resonant circuit when the other two are known. For a given frequency, f, and the desired inductance, L, the value of capacitance for the parallel circuit shown in Fig. 3 is determined by the intersection, C, of line AB and the capacitance scale.



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HAM TIPS

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Vol. 13, No. 2 June-July, 1953

A Bandpass Transmitter-Exciter Using an RCA 6146

Part I

By Richard G. Talpey, W2PUD*

Are you planning to build a new VFO, an all-band exciter, or a pi-network final? If so, we're sure that you will find it very worthwhile to read W2PUD's article before you begin. It is intended for those readers who want to build something other than a conventional transmitter.

This article differs from the usual how-to-build-it descriptive article in that it features a thorough discussion of the "groundwork" that preceded the final design. Because of the enthusiasm with which the active ham reads such a discussion, and the improbability of the average ham copying this transmitter to the last detail, this article has been divided into two parts. Part I contains a description of the transmitter; the constructional details will appear in Part II. This arrangement provides ample space for the author to expound on some very interesting ideas on the design of a modern multiband rig. A complete schematic diagram and parts list are included in Part I for those interested in getting an early start.

The excellent performance of the RCA-6146 beam-power amplifier at high frequencies, its maximum ICAS rating of 90 watts input for cw operation, its very low driving-power requirement (0.3 watt), and the elimination of the need for special shielding make this tube the logical successor to the 807 for use in an exciter of modern design.

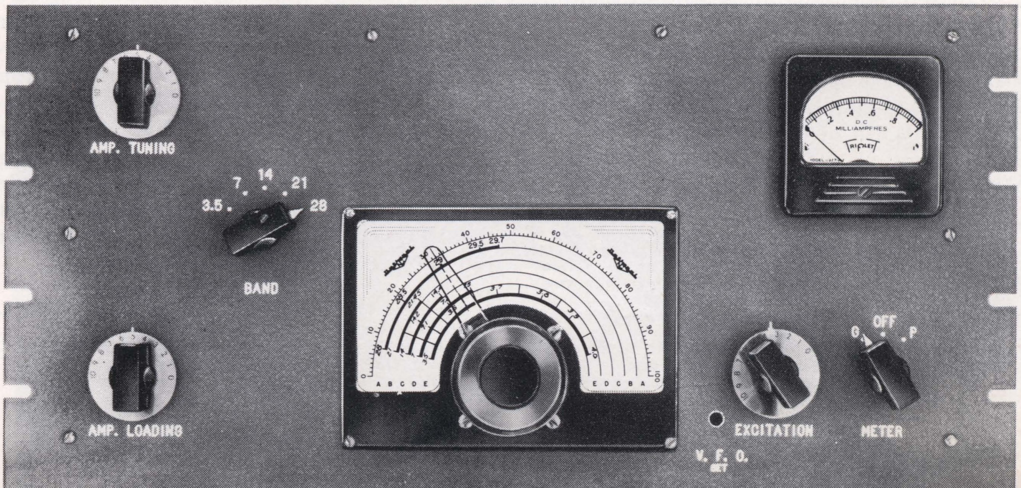
General Requirements

Early in the project, it was decided that the transmitter-exciter to be built around the 6146 should have the following features: (a) operation on the 3.5-, 7-, 14-, 21-, and 28-Mc bands by means of a single handswitch and VFO; (b) provision for break-in operation; (c) freedom from TVI; (d) reasonably simple construction; (e) minimum of tubes and controls.

The transmitter shown in *Fig. 1* provides all of these features. For ease of operation, this unit requires no tuning other than the VFO and the final tank; broadband double-tuned tank circuits are used in the exciter stages, and a tapped pi-L tank circuit provides flexible TVI-proof operation of the final am-

* *Tube Dept., Radio Corp. of America, Harrison, N. J.*

Fig. 1. Pick your band, set the VFO, tune and load the final, and you have an output of 65 watts cw or 45 watts for AM phone operation.



plifier. A keyed amplifier between the VFO and the first frequency multiplier eliminates any back-wave and permits full break-in operation.

An output of 65 watts cw or 45 watts AM phone is available on all bands.* Power requirements are 6.3 volts ac at 4.1 amp, 250 volts dc at approximately 100 ma for the exciter stages, and either 600 volts at 150 ma or 750 volts at 125 ma for the final amplifier. The 6146 operates well at reduced plate voltages and can be run at the full rated plate current of 150 ma.

Design Considerations

Heterodyne VFO. Keeping in mind the general requirements of the rig, the first consideration was the VFO. Initially, a heterodyne-type VFO was investigated to obtain break-in operation. This unit used an 8.5-Mc crystal beating with a VFO which tuned from 4.5 to 5 Mc to provide output over the 3.5-Mc band.

Several circuits were moderately successful, providing sufficient output and good keying in the mixer stage. Although these tests were carried out on the bench with rather haywire unshielded circuits, it was possible to eliminate the receiver backwave almost completely when the key was up. One of these circuits used a 6AK6 Clapp VFO, a 6C4 crystal oscillator followed by a 6AU6 buffer and a 5763 mixer. The 6AU6 was keyed, and a bandpass tank circuit was employed in the output of the mixer to attenuate the unwanted sideband and the two oscillator frequencies. The use of the 5763 as a mixer, however, required that an amplifer be used to bring the signal up to the proper level to drive the final on 75 meters.

The original lineup, using a 5763 amplifier/multiplier and 5763's in all of the multiplier stages, was viewed with some misgivings because the 5763 oscillated when operated as a straight-through amplifier. Various neutralization circuits were applied to the 5763 without success, the chief difficulty being the maintenance of proper phase opposition in the band-pass coupling circuits over the fairly large bandwidth of the 3.5-Mc band.

** The reader may ask why the frequency range of this transmitter does not include the 11-meter band. Considerable thought and experiment went into this possibility. In order to cover 3.3 to 4 Mc with a double-tuned circuit, the Q must be lowered to a value that makes the proper degree of coupling between coils very difficult to obtain; furthermore, the skirts of the response curve of the stage would be fairly broad. It was felt that the advantages of 11-meter operation do not justify the increased complexity or compromises in the design, e.g., an extension of the tuning range of the VFO down to 3.3 Mc results in the 14-Mc band occupying a smaller section of the dial.*

An even more serious difficulty arose when the band-pass tank circuit provided inadequate filtering thereby permitting a complex signal (containing both oscillator signals and their sidebands) to be applied to an amplifier which had to be driven hard enough to draw grid current (and thus present a non-linear impedance). Although the desired sideband was partially filtered out in the previous stage, there was sufficient voltage present at the unwanted frequencies, and the heterodyne signal which resulted from this non-linear mixing could only be characterized as a mess.

A little reflection shows that nothing other than the above results can be predicted when a high-level mixing system is used unless a filter having rigid requirements is used in the output of the mixer. (It is entirely possible to build a successful heterodyne VFO; several have already been described in the amateur-radio literature.) Mixing is best accomplished at low level, where unwanted sidebands can be filtered more easily without too much shielding.

The advantage of a mixer VFO lies mainly in the ease of keying and obtaining break-in, and in the stability which is gained by allowing both oscillators to run continuously. However, there are other ways to accomplish the same result with much simpler circuits.

Shielded VFO. The VFO finally chosen for this transmitter is one that has been in use in the author's shack for several years. The system is not novel; in fact, it has been used in several commercially-built transmitters, and has been described in the literature.* The VFO operates on 1.7 Mc. Sufficient shielding is employed so that it can be run continuously —keying is accomplished in the first amplifier stage following the oscillator.

In this system, the oscillator must be relatively free from harmonics and the design must not include any non-linear circuits between the VFO and the keyed stage. The VFO employs a Clapp oscillator which is especially suitable for this application because it is very stable; also, it is essentially a weak oscillator having a rather high Q and very little harmonic output. The particular variety of Clapp VFO chosen for this application has been described previously.** By running the oscillator at low plate voltage (40 volts) and following it with a high-gain keyed stage, it is possible to reduce the radiation to almost nil, so that the VFO may be run continuously without interference when the key is up.

** "A Solution to the Keyed-VFO Problem," by R. M. Smith, W1FTX, QST, Feb. 1950, pg. 11.*

*** "Some Notes on the Clapp Oscillator," by R. G. Talpey, W2PUD, QST, Jan. 1949, pg. 45.*

VFO and Keyed Amplifier. The complete circuit for the transmitter is shown in *Fig. 4.* The Clapp oscillator uses a single section of a 12AU7; the other section of this tube is a cathode follower which provides a low-impedance output that "can be led around the chassis" through a shielded cable to the grid of the 6AU6 keyed amplifier.

The use of a high-gain keyed amplifier makes it possible to operate the VFO with an output voltage of about 1 volt, thereby making the shielding problem easier to solve.

It was found desirable to mount the coupling capacitor and grid leak for the keyed-amplifier stage inside the oscillator shield compartment. This arrangement permits a short (¼-inch) length of signal lead to be exposed for connection to the grid of the keyed amplifier. Simple by-pass and decoupling networks in the power leads to the VFO compartment, plus the use of shielded wire for power wiring leaves little possibility for leakage from the oscillator.

The 6AU6 high-gain keyed amplifier operates close to class-A conditions. It provides good shielding and enough output to drive a 5763 (first doubler) which doubles to 3.5 Mc. Impedance coupling is used between the 6AU6 and the first doubler to reduce the number of tuned circuits.

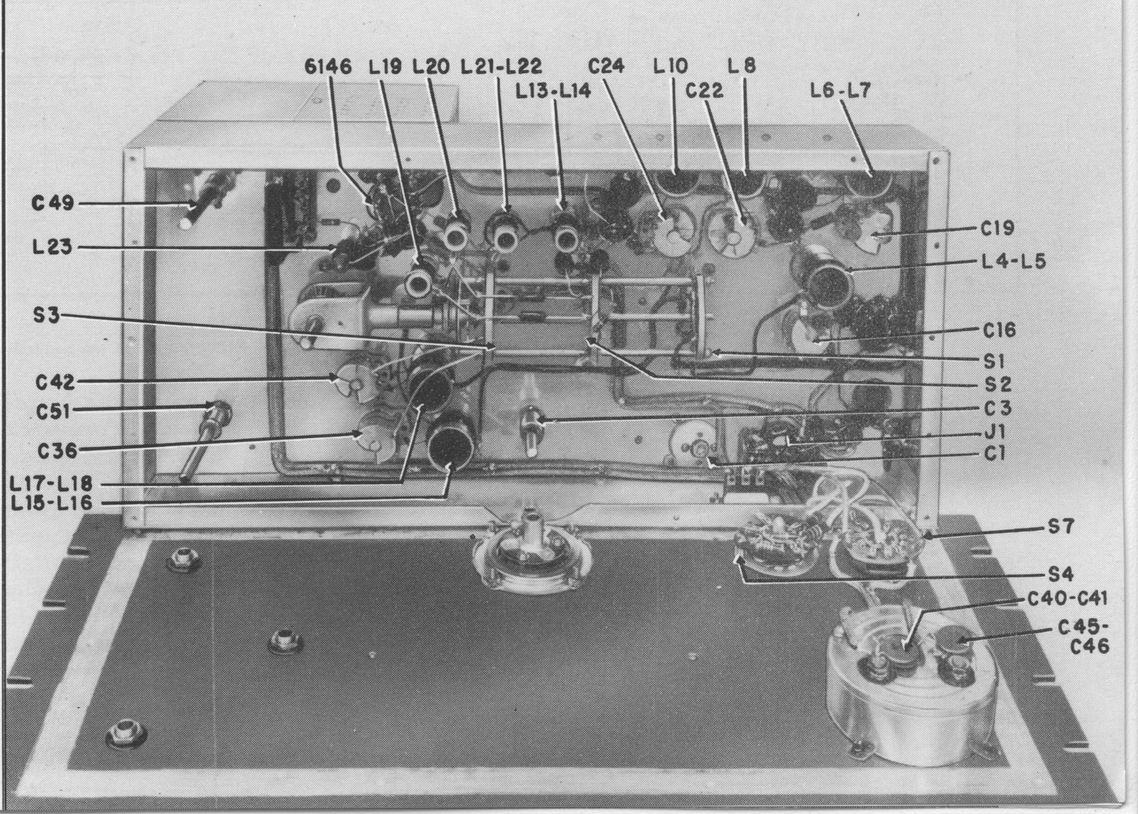
Coupling Methods For Bandpass Operation

In this transmitter, bandpass coupling circuits are used to eliminate the need for retuning the multiplier stages when the frequency of the VFO is changed. This arrangement was employed (instead of ganging the tuning controls of the multipliers with the VFO dial) to avoid a tracking problem and to minimize the number of restrictions on the physical layout of the exciter.

Broadband Tank Circuits. Although broadband resistance-loaded tanks were used in the past, they are no longer recommended because they are rather unsatisfactory for TVI reduction. The low Q's involved do not provide sufficient skirt selectivity and the possibility of transmission of several harmonics of the multiplier frequency can lead to possible misadjustments and considerable harmonic output.

Several exciters using broadband, double-tuned tanks in the multiplier stages have been described in the literature. All of these exciters employ critically-coupled or over-coupled transformers to achieve the broadband performance. The primary and secondary windings of such transformers can be wound on the same coil form or mounted close to each other with their axes parallel.

Fig. 2. Inside view of the transmitter. Note the area where the paint is removed from the panel for contact with the chassis. Also note the meter shield, the meter by-pass capacitors, and the shielded power leads—all essential TVI precautions.



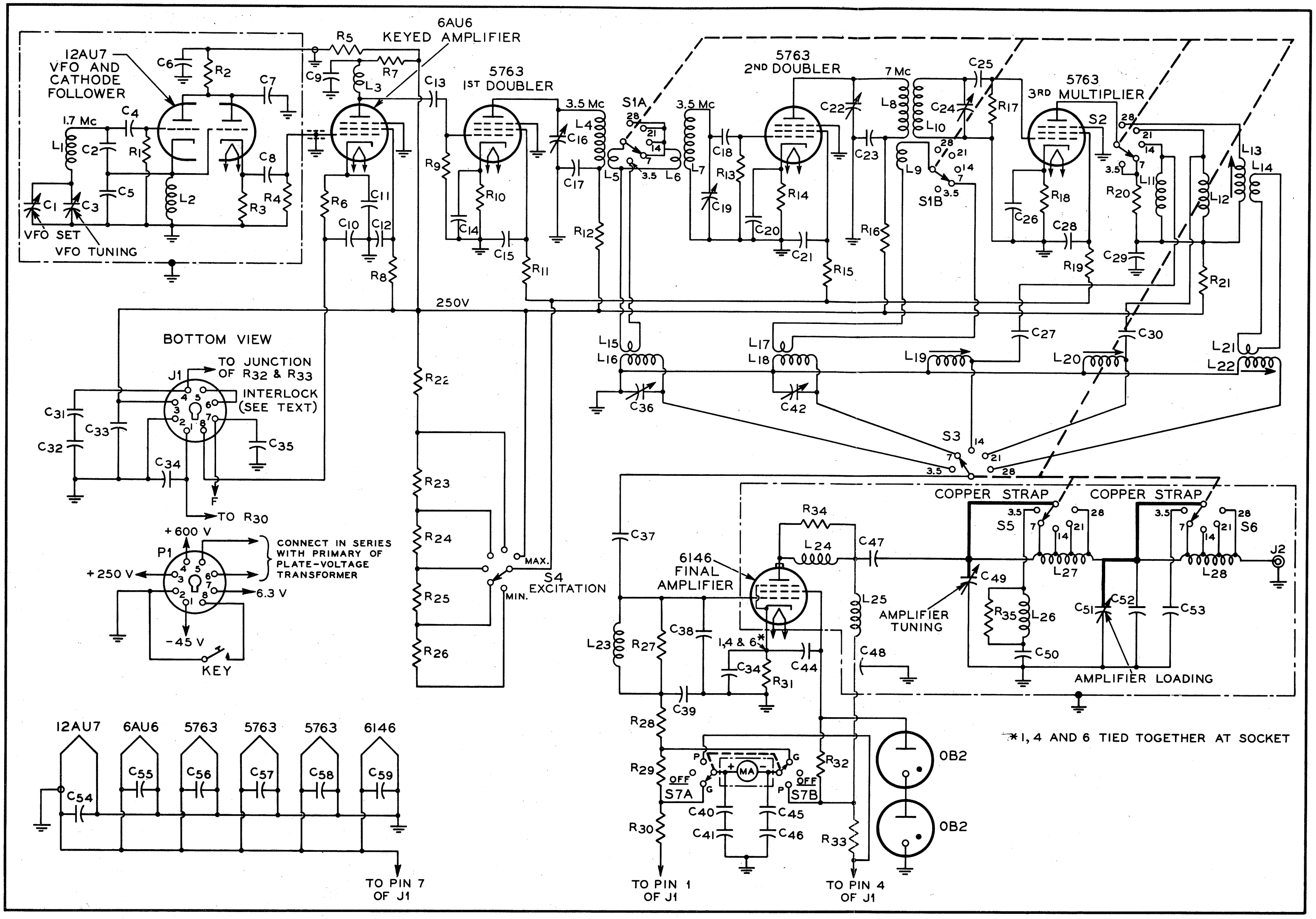


Fig. 3. Complete schematic diagram of the bandpass transmitter-exciter.

C_1, C_{22}, C_{24}, C_{25}, C_{42}	50μμf, midget padder (Hammarlund APC).
C_2, C_5	.001 μf, silver mica, 500 v.
C_3	30μμf, variable (Cardwell ET-30-ASP).
C_4, C_{37}, C_{50}	100 μμf, mica, 500 v.
C_6, C_7, C_9-C_{12}, C_{14}, C_{15}, C_{17}, C_{20}, C_{21}, C_{23}, C_{26}, C_{28}, C_{29}, C_{31}-C_{35}, C_{39}-C_{41}, C_{43}, C_{44}-C_{46}, C_{54}-C_{59}	.01 μf, disc ceramic, 500 v.
C_8, C_{13}, C_{18}, C_{27}, C_{30}	100 μμf, ceramic, 500 v (Erie GPK).
C_{16}, C_{19}, C_{36}	100 μμf, midget padder (Hammarlund APC).
C_{38}	25μμf, silver mica, 500 v.
C_{47}	.001 μf, mica, 2500 wv.
C_{48}	.001 μf, 500 v (Sprague Hypass).
C_{49}	100 μμf, variable, .030″ spacing (Bud CE-2004).
C_{51}	300 μμf, variable, .024″ spacing (Bud MC-910).
C_{52}	150 μμf, mica, 500 v.
C_{53}	470 μμf, mica, 500 v.
Dial	National SCN.
J_1	8-pin octal plug.
J_2	Coaxial connector (Amphenol 83-1R).
L_1	40 turns No. 24 enamel, 1½″ diam, 2½″ long (See text).
L_2, L_3, L_{11}, L_{12}	RFC, .5 mh (National R-50).
L_4	40 turns No. 24 enamel on National XR2 form.
L_5	3 turns No. 22 enamel—link, on same form as L_4.
L_6	3 turns No. 22 enamel—link, on same form as L_7.
L_7	32 turns No. 24 enamel on National XR2 form.
L_8	18 turns No. 22 enamel on National XR2 form.
L_9	2 turns No. 22 s.c. enamel—link, on same form as L_8.
L_{10}	22 turns No. 22 enamel on National XR2 form, mounted 1⅜″ (on(centers) from L_8.
L_{13}	14 turns No. 22 enamel, spaced to occupy ¾″ on Millen 69046 slug-tuned form.
L_{14}	1 turn No. 18 solid insulated—link, cemented in place over L_{13} (See text, Part II).
L_{15}	3 turns No. 22 enamel—link, on same form as L_{16}.
L_{16}	30 turns No. 24 enamel on National XR2 form.
L_{17}	3 turns No. 22 enamel—link, on same form as L_{18}.
L_{18}	14 turns No. 22 enamel on National XR2 form.
L_{19}	16 turns No. 22 enamel, spaced to occupy ¾″ on Millen 69046 form.
L_{20}	10 turns No. 22 enamel, spaced to occupy ⅝″ on Millen 69046 form.
L_{21}	1 turn No. 18 solid insulated—link, cemented in place over L_{22} (See text, Part II).
L_{22}	8 turns No. 22 enamel, spaced to occupy ¾″ on Millen 69046 form.
L_{23}, L_{25}	RFC, 2.5 mh (National R100U).
L_{24}	7 turns No. 24 enamel wound on R_{34}.
L_{26}	7 turns No. 24 enamel wound on R_{35}.
L_{27}	19½ turns of 2″-diam, B & W 3907 coil stock, tapped at 6th, 13th, 16th and 17th turns.
L_{28}	17 turns of 1″-diam, B & W 3105 Miniductor, tapped at 4th, 10th, 13th and 16th turns.
MA	0-1 ma (Triplett 327T).

NOTE All resistors ½ watt unless specified otherwise.

R_1, R_9, R_{17}	56K.
R_2, R_7, R_{12}, R_{16}, R_{20}, R_{21}	1K.
R_3	2.2K.
R_4	100K.
R_5	47K, 1 watt.
R_6	220 ohms.
R_8	39K.
R_{10}, R_{14}, R_{18}	330 ohms.
R_{11}, R_{15}, R_{19}, R_{22}	15K, 1 watt.
R_{13}, R_{24}	27K.
R_{23}	18K, 1 watt.
R_{25}	33K.
R_{26}	220K.
R_{27}	22K, 1 watt.
R_{28}	8.2K.
R_{29}	Meter shunt (See text, Part II).
R_{30}	560 ohms.
R_{31}	100 ohms, 5 watts.
R_{32}	30K, 10 watts.
R_{33}	Meter shunt (See text, Part II).
R_{34}	22 ohms.
R_{35}	33 ohms.
S_1-S_3	Centralab P123 Index with three type R switch sections spaced 2¼″ apart.
S_4	Centralab 1401.
S_5, S_6	Centralab 2510.
S_7	Centralab 1473.

Miscellaneous

Chassis	8″ x 17″ x 3,″ aluminum (ICA 29014).
Panel	8¾″ x 19,″ aluminum (ICA 8604).
VFO shield box	4″ x 5″ x 6,″ aluminum (ICA 29342).
Final shield box	8″ x 6½″ x 6″ (Made from two ICA 29344 Fleximount cases and 8″ x 6½″ x .062″ aluminum plate; See text, Part II).

When this type of transformer is adapted to a bandswitching system, either of two undesirable conditions usually arises: (1) The number of multiplier stages is increased because of the necessity of switching particular stages in or out of the lineup to obtain the correct output frequency. (2) The complexity of the switching necessitates a compromise in the physical layout.

When adjoining multiplier stages have their coils mounted close to each other (with their axes parallel), sufficient coupling can be provided if the Q's of the coupled circuits can be made high enough to obtain the proper coefficient of coupling.

Link-Coupled, Double-Tuned Coupler. If the primaries and secondaries of the tuned transformers are coupled by low-impedance links, it becomes feasible to build a broad-band exciter covering 3.5 through 28 Mc with only two or, at the most, three tubes—the usual number required for a conventional exciter.

The parts may be arranged for maximum efficiency and short leads, and the link switch may be mounted almost anywhere because it switches only low-impedance circuits.

The link-coupled, double-tuned coupler is considerably easier to adjust than the direct-coupled type because there are no large windings to be moved up and down on the coil forms. The links may be wound with stiff wire and conveniently slid over the primary and secondary windings. After the coupling

is adjusted, the links may be cemented in place.

In this transmitter, it was found convenient to use three different coupling methods; the choice of a particular coupling method for a given portion of the circuit was determined by the layout and required bandwidth.

Bandswitching the Multipliers

The grid of the final amplifier is switched to any of five resonant circuits by bandswitch S_3 and the drive is selected from the appropriate multiplier stage. The first 5763, doubling from 1.7 Mc, drives the final on 3.5 Mc. The link that is coupled to the plate circuit of this doubler is switched by S_{1A} to either the final grid circuit or the second doubler, a 5763 having its grid circuit tuned to 3.5 Mc. The output of this doubler is link coupled through switch S_{1B} to the final for 7-Mc operation.

The plate coil of the second doubler is mounted close to the 7-Mc grid coil of the third multiplier so that the two stages are coupled inductively without the use of a link circuit. This third multiplier is used to double, triple, or quadruple for output on 14, 21, or 28-Mc, respectively.

On 14 and 21 Mc, where the percentage bandwidths are small, the resonant circuit selected by S_3 functions as the tank. A choke (L_{11} or L_{12}) is used to feed plate voltage to the multiplier, and capacitance coupling is used between this multiplier and the grid circuit of the 6146.

On 28 Mc, the multiplier plate circuit is tuned by means of a slug in L_{13}, resonating with the tube capacitance. A link is run permanently to grid tank L_{22}, which is also slug tuned. Link switching is not needed here because this link is used for only one band. Switch S_2 in the plate of the multiplier selects the proper output circuit for operation on 14, 21, or 28 Mc.

The unused multipliers are left idling—a small amount of cathode bias is provided to hold the plate current at a safe value. This plate current, which is the same amount that flows when the key is up, is about equal to the operating plate current. Therefore, there is very little change in power-supply drain and no special regulation is demanded of the exciter power supply. The third multiplier, which is unused on 3.5 and 7 Mc, has a small resistor switched into its plate circuit to maintain plate voltage on the tube and to prevent the screen current from becoming excessive. A short circuit could have been used in place of the resistor, but it was felt that high-frequency parasitics might be encountered if a low-inductance plate circuit were used.

Excitation Control

Excitation to the final is controlled by adjustment of the screen voltage of the frequency multipliers. The screen grids of all the multipliers are supplied from a common bus, the voltage of which is controlled by tap switch S_4 and series resistors R_{22}-R_{26}. If it were not for the desirability of controlling the excitation to the final, the idle multipliers could be switched off when not in use, thus effecting some saving in the power drain; however, this arrangement would require two more switch sections.

6146 Bias

Grid bias for the 6146 is provided by three different means: cathode bias, a small amount of fixed bias (45 volts), and grid-leak bias. The original design contemplated the use of screen clamping of the final to eliminate the need for fixed bias. However, experience showed the combination method to be better suited to the 6146. Because of the husky cathode in the 6146, screen control is not as effective as in some other tetrodes, and ordinary clamp tubes do not reduce the plate current to a safe value when excitation is removed.

Even the use of a VR tube in series with the screen does not suffice where complete plate-current cutoff is desired. There seems to be a small amount of screen emission which allows the screen to assume a slightly positive potential, thus preventing complete cutoff. With the series VR tube and an ordinary clamp arrangement, the unexcited plate current is about 25 ma. Under this condition, the 6146 amplifies the noise generated by the high-gain multipliers and produces an annoying hiss in the receiver.

A small amount of fixed bias, conveniently obtained from a 45-volt battery (such as an RCA VS 114) obviates all this trouble, provided the screen voltage is not allowed to rise above the operating value and change the cut-off characteristic. A pair of miniature voltage-regulator tubes are used to hold the screen voltage at 210 volts when excitation is removed. These tubes may extinguish when excitation is applied and the screen current rises; however, such operation is not objectionable as long as the screen voltage is between 150 and 200 volts—high enough for efficient operation. For phone operation, it is desirable to keep the VR tubes extinguished to prevent shunting of the ac screen voltage. The value of the screen-dropping resistor is chosen to provide approximately 190 volts on the screen under normal operation; this value rises to

only 210 volts when the excitation is removed.

The stability of the final amplifier is improved materially by the use of a small mica capacitor connected directly at the socket from grid to ground. This capacitor helps to attenuate the grid harmonics and lessens the tendency toward oscillation by keeping the grid impedance low. A small amount of resistance loading is used across the grid circuit to help flatten the bandpass characteristic and to prevent the 'valley' in the overcoupled-circuit response curve from being too deep.

Pi-Network Tank Circuit

The pi-network tank circuit helps eliminate TVI and is well suited to all-band operation, particularly where bandswitching is desired. The pi network provides considerably more harmonic reduction than the parallel tank circuit without a sacrifice in amplifier efficiency. In regions where the TV signal strength is high, there is no need for additional filtering if reasonable design precautions are taken.

The network chosen for this transmitter was calculated from the curves given by Pappenfus and Klippel.* The only trouble encountered was the result of the initial assumptions. The plate impedance of the 6146, under normal operating conditions, is approximately 2,000 ohms or less—somewhat lower than that of most tetrodes. The pi network capacitances required for matching this rather low plate impedance to 50-ohm coax are fairly high if an operating Q of 15 is chosen for the 3.5-Mc band.

The importance of keeping the Q as high as this is rather dubious, particularly because it has never been adequately demonstrated that a high Q contributes materially to the reduction of higher-order harmonics when stray coupling is usually the source of most of the trouble. With a Q of 7, not low enough to reduce the amplifier efficiency, the network becomes more manageable and the values of the capacitances are reasonable. On the higher-frequency bands, the Q may be increased because the required capacitance is less.

L-Network

The complexity of the switching is not materially increased by the addition of an L network** between the pi and the antenna. The use of an L network offers two added advantages: (1) further reduction of the capacitance required to make the network fit the design curves; (2) additional harmonic attenuation. The pi network steps the impedance down to about 500 ohms, and the L network reduces it from 500 to 50 ohms. A little cut-and-try is necessary to obtain the proper taps on the inductors and the proper values of loading capacitance for the different bands if a Q meter is not available for measurement of these values beforehand. *It is well to note that the values of the loading capacitance given in the charts in the previously mentioned reference are for optimum or full load; the capacitance must be increased somewhat to provide for tuning up and lighter loading.*

A certain amount of compromise in the matter of flexibility of adjustment must be accepted in a multiband rig, because the required capacitance values vary greatly when tuning from 3.5 to 28 Mc especially where a single wide-range capacitor is to be employed. However, constants chosen for the tank provide ease of adjustment without unduly complicating the switching. On 3.5 Mc, it is necessary to switch in additional capacitance to provide proper operation without compromising the high-frequency performance.

In a complex multiband tank circuit, the use of parallel capacitances may cause high-frequency resonances and parasitics, and this case was no exception. Also, lead lengths in a bandswitching arrangement sometimes prove vulnerable to high-frequency resonances. During the bench stage of the development work on this transmitter, several rf burns were obtained from the "cold" end of the shunt capacitors before the exact nature of the parasitic resonance was recognized. However, once the parasitic paths were discovered, the judicious use of a grid-dip meter indicated where corrective measures were needed.

Because of its high power sensitivity, the 6146 cannot be expected to be free from parasitics—particularly since its high-frequency performance is so good. It is necessary, therefore, to use a parasitic choke in the plate lead and to load this choke with resistance to keep its Q low at high frequencies.

The shunt tank capacitor, C_{50}, resonating with the main variable tank capacitor on 3.5 Mc, developed a parasitic which was eleminated by the addition of choke L_{26} to the circuit. The resistance loading (R_{35}) across this small inductance introduces enough high-frequency loss to suppress the parasitic oscillation without affecting the low-frequency performance.

As a TVI precaution, the shunt padding capacitors used for both tuning and loading should be checked to make certain that they do not resonate in any of the TV channels.

(To be continued in the next issue of HAM TIPS.)

* *"Pi Network Tank Circuits," by E. W. Pappenfus, WØSYF, and K. L. Klippel, WØSQO, CQ, Sept. 1950, pg. 27.*

** *"Further Notes on Pi & L Networks," by E. W. Pappenfus, WØSYF, and K. L. Klippel, WØSQO, CQ, May 1951, pg. 50.*

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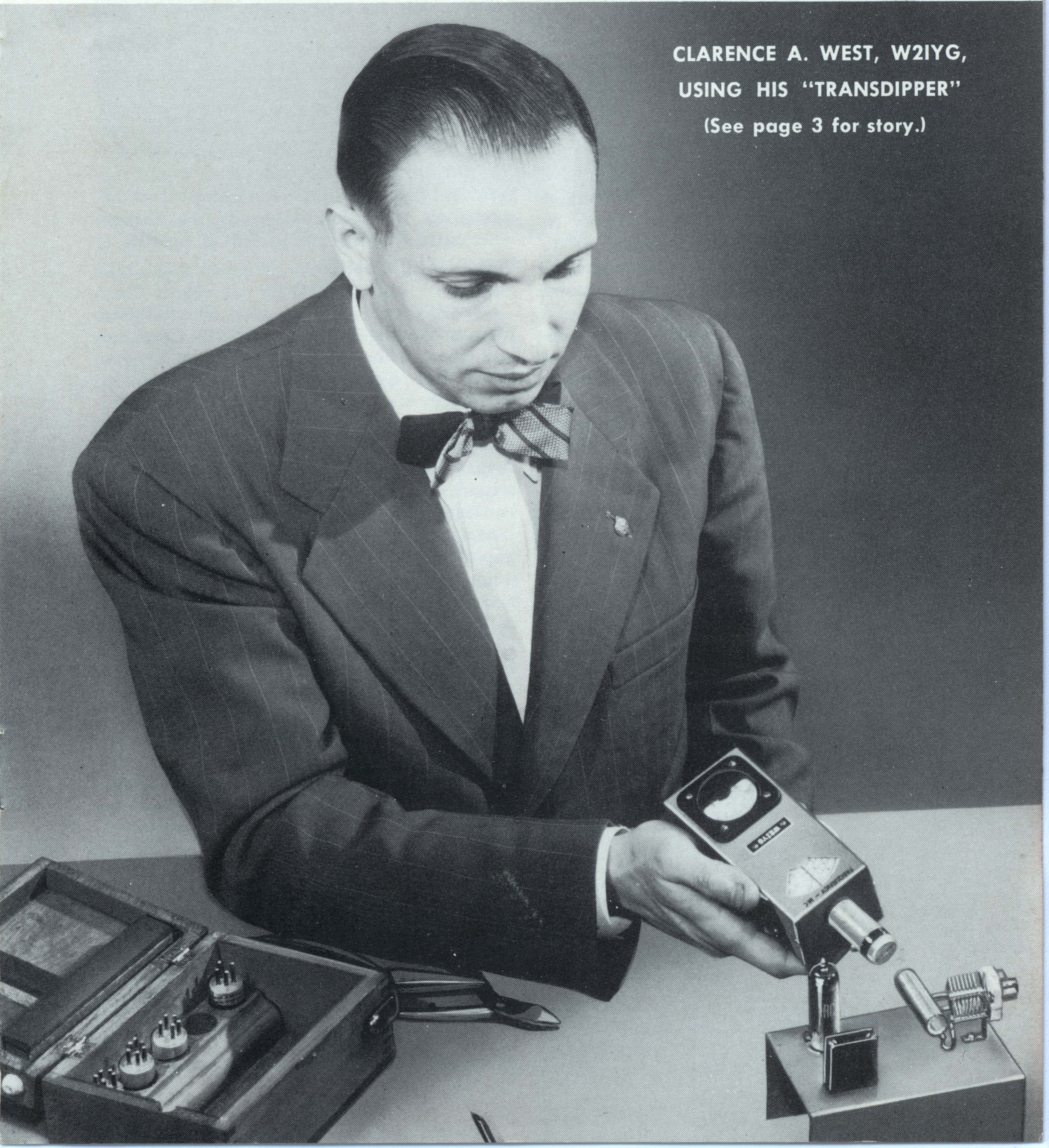


CLARENCE A. WEST, W2IYG, USING HIS "TRANSDIPPER"

(See page 3 for story.)

A Bandpass Transmitter-Exciter Using an RCA 6146

Part II

By Richard G. Talpey, W2PUD*

THE TRANSMITTER is built on an 8 by 17 by 3-inch aluminum chassis. The construction is somewhat unconventional inasmuch as the controls project out of the bottom of the chassis through a standard 8 ¾-inch relay-rack panel which forms the front of the shield enclosure.

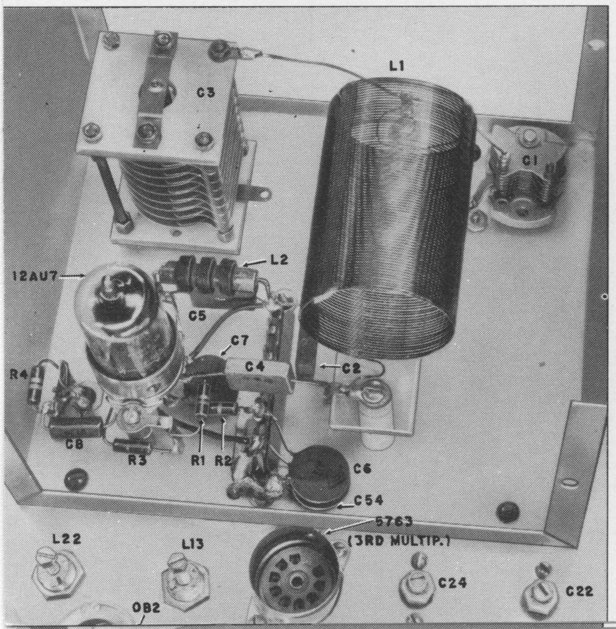
The VFO is completely housed in the smaller aluminum box shown in *Fig. 1*. The larger box shields the 6146 final amplifier. The layout of the components of the VFO and the final-amplifier plate circuit are shown in *Figures 2* and *4*, respectively. Most of the other components are shown in *Fig. 3* which is a close-up view of *Fig. 2* (Part I). This method of construction permits the bandswitches to be coupled with a single right-angle drive. This arangement provides single-knob control of all bandswitches, thereby facilitating the layout.

The shield for the final-amplifier plate circuit was made from two aluminum cases (See Parts List, Part I). The unflanged portions were discarded, and the flanged sections were overlapped in the center. A sheet of aluminum was cut to fit the top.

The bandswitch is mounted in the center of the chassis so that the switch sections are located near the multiplier tubes. The bandswitch is made from a standard index assembly and separate switch sections selected according to function. A standard two-section switch for the final tank is mounted above the chassis in line with the bandswitch knob; the switches for the multipliers are coupled to the right-angle drive located inside the chassis. The other controls are placed to provide a neat panel arrangement.

This second and concluding part of W2PUD's article contains the constructional details and adjustment procedures. A complete description of the circuit together with a schematic diagram and parts list appeared in Part I in the June-July issue of HAM TIPS. (If you missed Part I, ask your RCA Distributor for a copy; if his supply has run out, write to RCA, Commercial Engineering, Harrison, N. J.)

Fig. I. Inside view of the VFO (with cover removed). Note that coupling capacitor C_8 and R_4, the grid resistor for the 6AU6 keyed amplifier, are located in the VFO compartment (See text).



VFO

The VFO coil, L_1, was wound by hand on a piece of mailing tube covered with a layer of wax paper. The wire was wound over the wax paper and spaced to occupy the required length. A few extra turns were included to allow for final trimming. A coat of household cement was applied in three longitudinal stripes 120° apart to secure the winding. A second coat was applied after the first coat hardened. The mailing tube was then collapsed and withdrawn along with the wax paper. Finally, each cement stripe was given one more coat of cement (inside and out) to make the coil rigid. After trimming, the whole coil was cemented to a ½ by 1/16-in. poly strip which was mounted on ceramic standoff insulators. This type of coil is very rugged and has the high Q required for the Clapp oscillator. The coil must be mounted as far from the sides of the shield as possible, because the shield acts like a shorted turn coupled to the coil and will reduce its Q materially if the spacing is made too small. Care should also be taken to see that the tuning capacitors and other parts cannot move with respect to the 'hot' end of the coil, which is the end connected to the capacitors.

The socket for the 12AU7 is mounted on metal spacers to permit the connectors to be made easily. All of the VFO components (as well as connections) should be made as rigid as possible because the stability of a Clapp oscillator depends to a great extent on its

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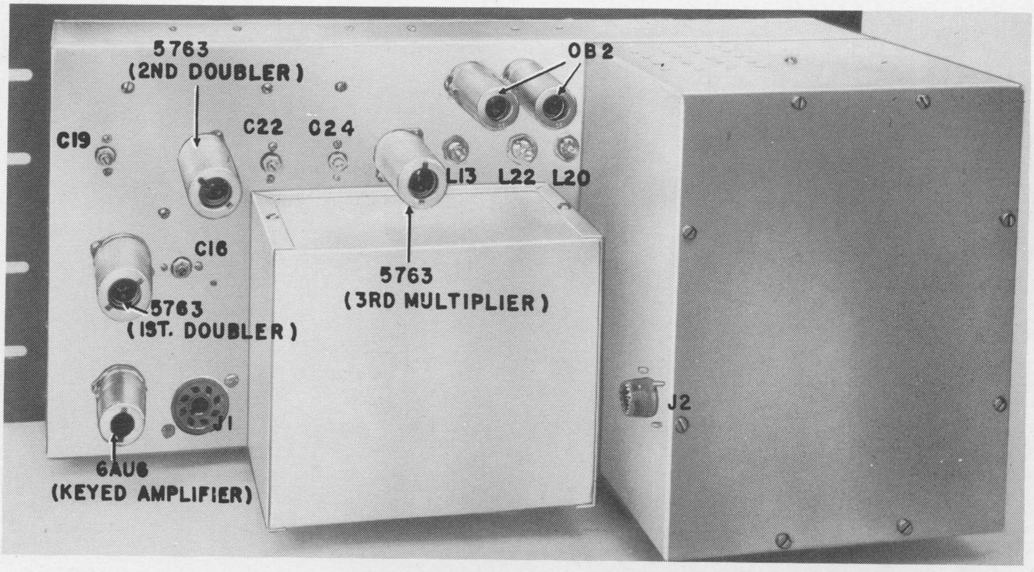


Fig. 2. Rear view of the transmitter. Complete shielding plus the pi-L tank circuit for the 6146 make this unit a "TVI-free" transmitter. The small shield box contains the VFO; the final amplifier is housed in the larger box.

mechanical construction. The grounds to the shield braids for the power leads should be made near the hole where they enter the compartment, and the by-pass capacitors should be grounded to this same point.

General Layout

As many of the holes as possible should be drilled beforehand to eliminate difficulty later on. The paint should be scraped off the back of the panel where it butts against the flange of the chassis to insure a good rf connection and to prevent rf leakage. Careful layout of the panel is required to insure that the shafts for all controls line up properly. Be sure to use panel bearings where the shafts protrude through the panel to prevent the shafts from becoming antennas for TVI. It is helpful to drill the holes for the shield cans and make a trial assembly of the shields before mounting any of the major components. Trial fits for shaft line-up for the bandswitch and tuning capacitors are also recommended.

"First-Layer" Wiring

After making certain that everything will fit where intended, the tube sockets may be mounted and the heater and power wiring started. *All grounds for each stage* are made to lugs bolted under the tube-socket lugs. Components which are not mounted directly on the tube sockets are mounted on tie lugs bolted to the sides of the chassis. All of this "first-layer" wiring is best done before assembly of the bandswitch and coils.

Power is brought into the transmitter by means of an octal socket, and all leads are by-passed at the socket to a common ground point (to which are also tied the shield braids of the power wiring). Pins 5 and 6 on power plug P_1 are connected by a jumper on socket J_1 This arrangement serves as an interlock for the external power supply by preventing application of power to the primary winding of the plate-voltage transformer when plug P_1 is removed from J_1. By-pass capacitors for the 600-volt leads are made from two 0.01-μf, ceramic-disc capacitors connected in series to provide adequate voltage rating. The by-pass capacitor for the high-voltage lead to the final-amplifier plate is a Hypass unit, mounted through a hole in the chassis and supported

COVER PHOTO

Clarence A. West, W2IYG, of the RCA Tube Department's Commercial Engineering section is shown checking the resonant frequency of a tuned circuit with the aid of his "Transdipper" — a grid-dip oscillator employing an RCA 2N33 point-contact transistor in place of the usual vacuum-tube oscillator.

Developed in W2IYG's shack, this experimental unit is believed to be the first grid-dip oscillator using a transistor and covering five amateur bands (1.7 to 33 Mc). Probably the smallest grid-dip oscillator in existence, this complete unit is housed in a metal case measuring only 5 by 2¼ by 2¼ inches. The Transdipper is powered by a self-contained 22½-volt, hearing-aid battery (an RCA VS084).

Clarence will be remembered by many of the readers of HAM TIPS for his unusual article, "The Big Hunt (or) De-TVIing a 600-Watt, 14-Mc Transmitter," (Summer, 1951 issue) which outlines a straightforward method for eliminating TVI.

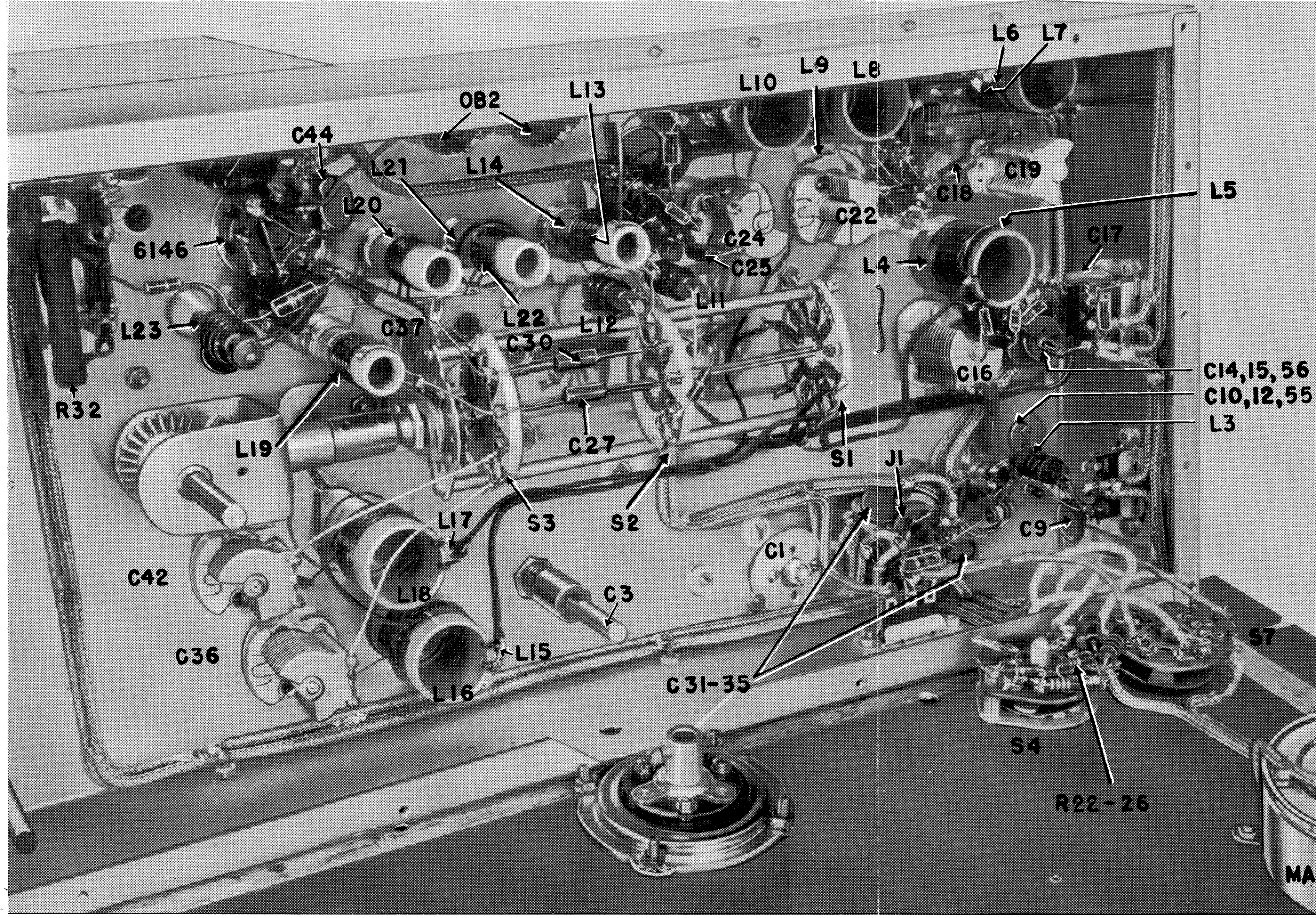


Fig. 3. Inside view of the chassis. This is a close-up of the same view shown in Fig. 2 in Part I of this article. Note that all power and heater leads are wired with shielded wire which is clamped to the chassis at convenient points.

by a small bracket as shown in *Fig. 4.*

Coils

After the preliminary wiring is completed, the bandswitch and the coils may be mounted. The coils should be wound according to the coil specifications given in the Parts List (Part I). Before they are mounted, the coils (with the exception of the link windings which will have to be adjusted later) should be given a coat of polystyrene coil dope. To obtain a high coefficient of coupling, the links are wound over a layer of cellophane tape on top of the main windings of the 3.5-Mc coils (L_4, L_5, L_{15}, and L_{16}).

All other links are wound at the "cold" end of the coils with provisions to move them slightly during line-up. Links L_{14} and L_{21} are made from a single length of No. 18 stiff, insulated wire and supported by cement on L_{13} and L_{22}, respectively, after final adjustment. Link connections to the bandswitch and between various coils are made with 75-ohm Twinlead.

Adding the VFO

After the VFO section has been constructed, it may be placed onto the main chassis at any convenient time. The output lead connects directly to the grid of the 6AU6; make certain that the portion projecting from the braid is as short as possible. Because this lead is in the low-impedance output circuit of the cathode follower, its length is not critical. Grid capacitor C_8 and resistor R_4 are placed inside the VFO shield to preclude any possibility of radiation from exposed parts.

Connections to Panel

Initially, the leads to the switches on the panel should be longer than needed so that it will be convenient to allow the panel to rest on the bench while initial adjustments are made. After the adjustments are completed and the unit is ready for "buttoning up," these leads may be shortened and connected to the switches; they should be just long enough to allow the panel to be swung out.

TVI Precautions

The rear of the meter case is covered with a shield cut from an evaporated-milk can. Fortunately, these cans are just the right size and can be easily cut with a pair of tin snips. The particular make of meter chosen (See Parts List in Part I) is slightly shorter (behind the panel) than some others and does not interfere with the coils which are mounted inside the chassis. The meter shunts, R_{29} and R_{33}, were wound with resistance wire to provide full-scale readings of 200 ma for the final plate current and 10 ma for the final grid current, respectively.

Final Amplifier

The coils for the pi network were cut from coil stock as noted in the Parts List (Part I), and no difficulty should be encountered if the taps are located as shown in the coil specifications. Coil L_{27} is mounted to the chassis by means of a small bracket which is attached to one of the plastic strips which was left a bit longer for this purpose. Coil L_{28} is supported by means of its leads, all of which are short. The output lead from L_{28} to the coax connector is shielded to reduce its inductance and to reduce stray pickup. Padding capacitors C_{50} and C_{53} are mounted between the bandswitch and ground lugs located directly underneath.

All under-the-chassis ground connections for the final amplifier are made to a lug which is mounted *on top* of the chassis and bent down through a clearance hole to receive the under-chassis leads. This arrangement *keeps all rf paths on one side of the chassis* and as short as possible. Copper strap is used for rf connections in the final amplifier to reduce inductance and keep spurious resonances at the highest frequency.

Adjustments

After the wiring has been completed, the rig is ready for lining up; the lineup may be done once and then forgotten. Remove all tubes except the 12AU7 from their sockets and test the VFO with the shield off. Adjust C_1 to set the band edge, and set C_2 for minimum capacitance to make certain that the band is covered. Some cutting of L_1 may be necessary

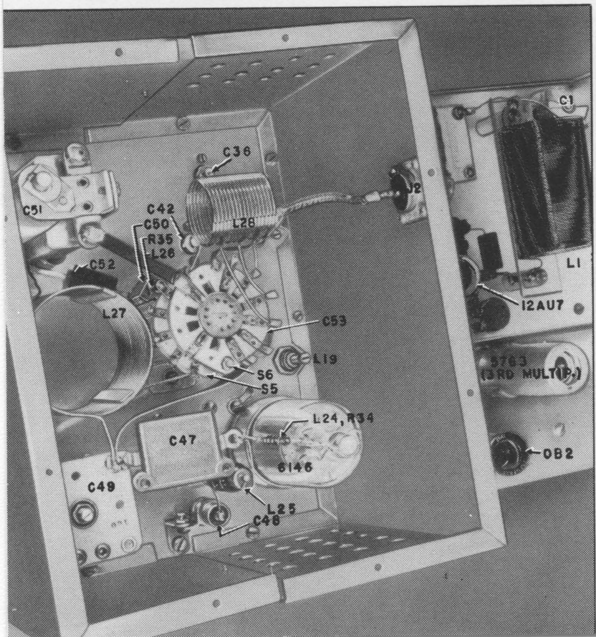
to make the band fit the dial fully. Put the shield on the VFO, and check to determine whether the VFO can be heard in the receiver. If the shield is tight and the decoupling is done properly, the VFO will not be audible.

A milliammeter should be inserted in the 250-volt lead during the lineup procedure to check plate currents. A high-resistance, dc meter such as an RCA VoltOhmyst® will be found useful for reading the rectified grid voltage, although a milliammeter wired temporarily in series with the ground end of the grid resistor will also serve the purpose. The connection between the meter and resistor should be by-passed if this latter method is used. With the 6AU6 and the first 5763 in their sockets, about 2 ma of grid current will flow in R_9 when the key is down. (Link L_5 should have its coupling reduced, and the first doubler tank should be tuned to resonance.)

Insert the 6146; with the plate voltage off and the bandswitch in the 3.5-Mc position, grid current should flow in the 6146 when the grid tank is tuned to resonance. Connect a 1,000-ohm carbon resistor temporarily across L_{16} and set the VFO to about 3.7 Mc. Slide links L_5 and L_{15} down over the coils slightly and resonate both circuits. The 1,000-ohm resistor reduces the Q of the coupled circuits to a low value, and in so doing, reduces the coefficient of coupling (dependent upon the Q). The undercoupled circuits can be peaked easily without interaction.

The grid current under this condition will be fairly small, but enough to indicate resonance. After the circuits have been tuned to resonance, remove the temporary resistor and check the grid drive over the band. It should have two peaks near the ends of the band and a valley in the center. If necessary, readjust C_{16} and C_{36} slightly so that the drive is fairly uniform over the band. A couple of tries may be necessary to obtain the right coupling between the link and the tuned circuits for the best uniformity of drive. The above procedure should be repeated each time in tuning up.

Fig. 4. Beam-power final — 1953 design! Copper strap is used to reduce lead inductance between the bandswitch and the tuning and loading capacitors. The shield box is perforated above and below the 6146 for adequate ventilation.



Next, insert the second doubler tube and turn the bandswitch to 7 Mc and set the VFO to 7.2 Mc. Connect the grid-current meter to R_{13}, and connect the 1,000-ohm resistor across L_7. Couple L_6 to L_7 and resonate the circuit with C_{19} without touching the adjustment of C_{16}. Removal of the 1,000-ohm resistor should now provide nearly uniform drive to the second doubler over the range of the VFO from 3.5 to 3.72 Mc. Again, the spacing of the links may have to be changed a couple of times to obtain the best results. The grid drive to the final amplifier through L_9 may now be adjusted by the same technique, although it will usually be unnecessary to use the 1,000-ohm resistor for the bandwidth required to cover the 7-Mc band. (The bandwidth of the circuit containing L_4 and L_7 must be broad enough to cover the 28-Mc band, whereas the plate circuit of the second doubler when coupled to the final grid need only cover 7 to 7.3 Mc.) Adjust C_{22} and C_{42} to provide uniform drive over the 7-Mc band.

Now, connect the 1,000-ohm resistor across L_{10} and resonate this circuit with C_{24} (at 7.2 Mc) with the aid of the grid meter in series with R_{17}. Do not readjust C_{22} unless it is necessary in order to make the drive to the third multiplier uniform over the range of the VFO from 3.5 to 3.7 Mc. If C_{22} has to be readjusted, go back and check the final grid drive on 3.5 Mc to be sure it has not been altered. Remove the resistor again and check the drive to the third multiplier. The location of L_{10} with respect to L_8, as given in the Parts List (Part I), should be about correct; however, this spacing may have to be changed slightly if the coils have not been wound exactly as described. L_{10} should not be closer to L_8 than is necessary for the required bandwidth for 28-Mc operation.

The difficult part of the lineup is now over and you may relax. The slugs in L_{19} and L_{20} may be adjusted to peak the final grid drive in the center of the 14- and 21-Mc bands, respectively. The 1,000-ohm resistor loading should be repeated on L_{22} and L_{13} to provide uniform drive across the 28-Mc band.

Go back and check the drive on each band and readjust wherever necessary. Then lock all capacitors and slugs. Apply a dab of cement to secure the links to the coils – you will not have to adjust these circuits until you rebuild!

Power may now be applied to the final amplifier. It is best to start at reduced plate voltage with a series resistor in the high-voltage lead. Connect a 50-ohm dummy load to the output jack with a pilot lamp across it. On any band, with C_{51} at maximum, C_{49} should be rotated to obtain a dip in plate current. The dip will be more pronounced on the higher frequency bands because the required capacitance for light loading will be less. Decreasing C_{51} will raise the plate current and the power output. Capacitor C_{49} should always be tuned for minimum plate current after C_{51} has been changed or the pi network will not behave correctly for best harmonic reduction. The presence of parasitics can be determined by reducing the fixed bias until the amplifier draws about 100 ma with the key up. Rotate C_{49} and note whether there are any changes in plate current. If there are, the amplifier is oscillating and the frequency of the parasitic oscillation should be determined with a grid-dip meter or wavemeter. During the design, the addition of L_{24} and L_{26} removed the last traces of parasitics and no tendency to oscillate was ever noted at the operating frequency.

TVI Check

With the panel and shields bolted securely, and a shielded dummy load connected to the output, no TVI was encountered with the transmitter on the bench beside a TV receiver protected with a high-pass filter. This test was made 30 miles from the TV transmitter. An inefficient TV antenna was used on the receiver which caused considerable snow on most channels. Removal of the shield from the dummy load produced crosshatching on some channels when the transmitter was operating on 14, 21, or 28 Mc. (The if amplifier in this receiver was not in the 21-Mc band!) When the 6146 plate circuit was tuned off resonance, the weak channels were obliterated – dramatic proof that the final tank must always be tuned to resonance. In regions where TV signal strength is low, a low-pass filter may be required to reduce TVI to a minimum.

Antenna Matching

The pi-L network will accommodate slight variations from the 50-ohm antenna impedance it is designed for; if the coax is not reasonably well matched, some trouble may be experienced in loading the final. A standing-wave bridge is invaluable for checking line match, either with direct feed or a line feeding an antenna tuner.

Keying

Very satisfactory keying was obtained without the use of a key-click filter. Because the multiplier stages and the final are not overbiased, no appreciable squaring of the wave shape results and the keying is clean, but not hard. If a softer note is desired, some filtering may be used provided that the cathode resistor of the 6AU6 is altered to take into account any resistance in the filter. The bias on the 6AU6 should be kept between 1 and 1.5 volts.

Modulation

The usual precautions in modulating any tetrode amplifier apply to this transmitter. The screen and plate are modulated together – about 40 watts of audio should be available. The use of a fixed screen supply for the 6146 is not recommended for phone operation.

A Few Afterthoughts

After the conclusion of such a project it is natural to wonder what possible improve-

Table of Voltages & Currents *(Typical at 7 Mc)

Tube	E_p (volts) Key Down	E_p Key Up	I_p (ma) Key Down	I_p Key Up	E_{g2} (volts) Key Down	E_{g2} Key Up	I_{g2} (ma) Key Down	I_{g2} Key Up	E_{g1} (volts) Key Down	E_{g1} Key Up	I_{g1} (ma) Key Down	I_{g1} Key Up
12AU7	45	45	6**	6**	—	—	—	—	—	—	—	—
6AU6	240	240	7	0	150	265	2.2	0	—	0	—	—
5763	240	240	20	17	145	180	1	1	—	-7	—	—
5763	240	240	18	19	130	170	1.5	1.5	—	-7	—	—
5763	240	220	14	19	160	180	1.0	1.2	—	-7	—	—
6146	600	650	150	10	200	210	15	—	-85	-45	3	0

* Heater voltage: 6.3 v. Supply voltages: 260 v and 600 v. ** Both sections.

ments could have been made, given the benefit of hindsight. Among these afterthoughts might be included the following:

(1) Bandspreading of the VFO to make the narrow bands easier to tune.

(2) Substitution of slug-tuned coils and fixed capacitors for the tuning capacitors in the low-frequency stages.

(3) Several changes in mechanical layout to facilitate wiring and improve the appearance. But as one who enjoys rebuilding occasionally, these changes were left for another session.

Acknowledgment

The author wishes to thank Mr. George Grammer, W1DF, for his helpful correspondence on the matter of harmonic response and Q of the pi network, and Mr. George D. Hanchett, Jr., W2YM, for his encouragement and many helpful suggestions.

Errata

There are four errors in the parts list on page 5 of the June-July, 1953 issue of HAM TIPS. L_1 should have 80 turns instead of 40; L_{28} is made from B & W 3015 Miniductor instead of 3105, and C_{48} should have a rating of 1,000 wv instead of 500 v. C_{25} should be listed with C_4, etc.

RCA TRANSISTORS NOW COMMERCIALLY AVAILABLE

The commercial availability of four RCA transistors was recently announced in an RCA Tube Department ad appearing in several trade publications.

The four types of RCA transistors announced are:

2N32—Point-contact type designed for large-signal applications such as switching circuits.

2N33—Point-contact type designed for oscillator applications up to 50 Mc.

2N34—Junction p-n-p type designed for low-frequency, low-power amplifier applications.

2N35—Junction n-p-n type designed for low-frequency, low-power amplifier applications.

Bulletins containing characteristics and technical information on these RCA transistors may be obtained by writing to RCA, Commercial Engineering, Harrison, N. J.

Because of the heavy demand for these transistors, please bear with us if your RCA distributor is out of stock.

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Joseph Pastor, Jr., W2KCN
Editor

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HAM TIPS

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Volume 13, No. 4 December, 1953

A Precision "Slick Whistle" for 3.5 to 4 Mc

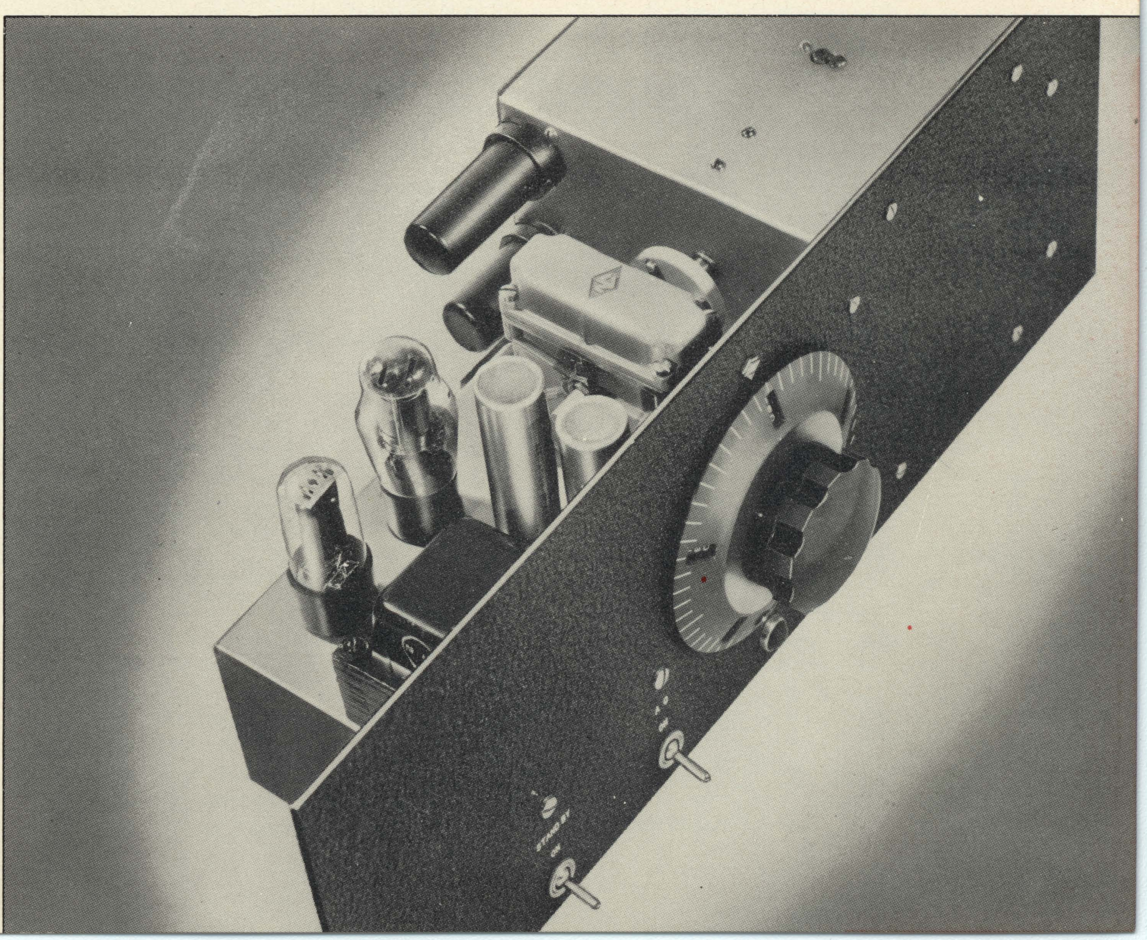
500-Kc Band Covers Approximately 500 Dial Divisions*

By F. S. Barkalow,† W2BVS

AFTER several contacts with hams who are "rock bound," one wonders why these operators handicap themselves by not employing a VFO. After receiving a few compliments on the operation of this VFO, the author asked a few of these hams why they didn't build a VFO. Most answers indicated that these hams postponed building a VFO because they assumed that frequency drift and questionable accuracy of calibration characterize all home-

* See caption for Fig. 1.

† RCA Tube Dept., Harrison, N. J.



made VFO's.

Stability and Accuracy

These were the watchwords! The VFO described in this article features rugged mechanical design plus voltage regulation to help insure frequency stability. Further assurance against frequency drift is obtained by operating this unit with its plate voltage on continuously during transmission, i.e., as a non-keyed VFO.

The problem of obtaining useful frequency calibration was solved by using a straight-line-frequency tuning capacitor together with a precision dial. Using this scheme and readily-available components, a roughly linear frequency-calibration curve has been obtained (See *Fig. 1*). Furthermore, the 500-Kc band (3.5-4 Mc) covers 497 of the 500 dial divisions. Thus, the actual frequency of the VFO (in Kc) is roughly equal to the dial reading plus 3,500.

This VFO has a high-impedance output circuit and works nicely into the crystal socket of a pentode oscillator; however, it has sufficient output to drive such tubes as an 807 or 6146 on 80 meters. For operation on 40 or 20 meters, external doubler stages are required.

General Description

The first stage employs a 6J5 in the widely used and reliable Clapp oscillator circuit. For additional output and isolation of the oscillator, a 6AG7 buffer is used. There is no tracking problem because the buffer employs an untuned tank circuit having low Q. The VFO has a conventional self-contained power supply utilizing a 5Y3-GT rectifier and an OD3 voltage regulator.

Because of the shielding provided by their metal shells, the oscillator and buffer tubes are mounted outside the oscillator box where their heat dissipation cannot affect the frequency stability. The use of silver-mica fixed capacitors, rugged, bus-bar wiring in the frequency-determining circuit, and regulated voltage on the oscillator plate and buffer screen, further contributes to the frequency stability of this unit.

Because the 500 divisions of the dial correspond to 180° of rotation, only a 180° portion of the 270° of rotation of the straight-line-frequency tuning capacitor C_2 is used. Originally, this VFO employed a tuning capacitor of the straight-line capacitance type. Substitution of the only available (locally) straight-line-frequency capacitor did pose a problem, however. The dial-shaft rotation (clockwise for an increase in number) did not correspond with the rotation of the tuning capacitor (counterclockwise for a decrease in capacitance, or increase in frequency). This problem was solved by removing the rotor and stator plates from their respective mounts and turning them over 180° and replacing them exactly in the order in which they were re-

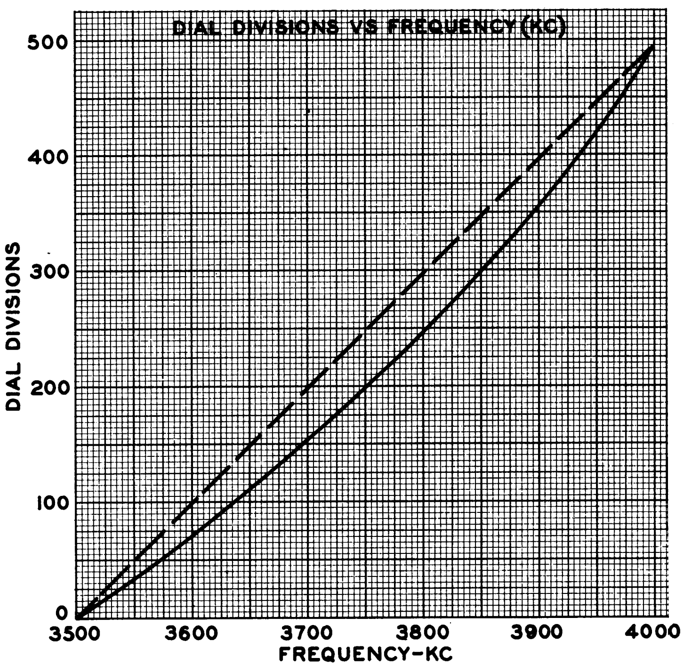


Fig. 1. Calibration curve showing frequency vs dial reading. If the calibration curve coincided with the straight line shown, the dial reading plus 3,500 would equal the VFO frequency in kilocycles. However, the dial readings have more utility than those on an arbitrary scale in that they roughly indicate the number of kilocycles above the low-frequency end of the band.

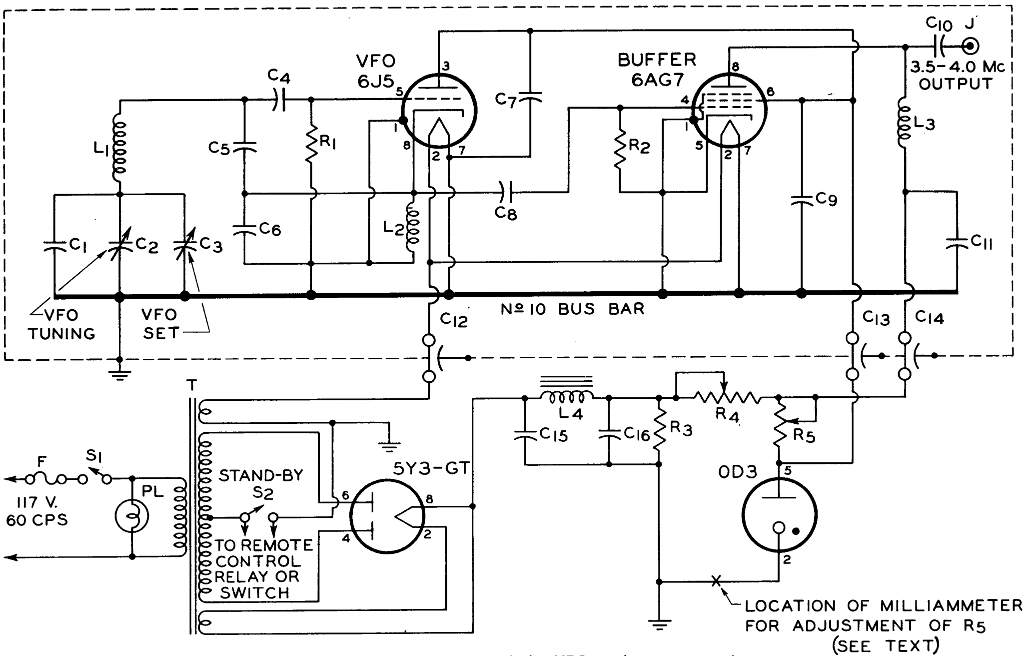


Fig. 2. Schematic diagram of the VFO and power supply.

C_1, C_4, C_8, C_{10}	100 μμf, silver mica (El-Menco CM-15-E-101-J).
C_2	75 μμf, variable (National SE75).
C_3	50 μμf, variable (Bud LC2079).
C_5, C_6	.001 μf, silver mica (El-Menco CM-30-102).
C_7, C_9, C_{11}	.01 μf, disc ceramic (El-Menco).
C_{12}, C_{13}, C_{14}	.0015 μf, feed through (Erie 362-152).
J	Connector (Cinch-Jones S-101).
L_1	23 turns, No. 16 enameled, spaced to occupy 2½ in., 2 in. diam (B & W 3907 coil stock).
L_2	RFC, 2.5 mh (National R-100).
L_3	RFC, 5.0 mh (National R-100).
PL	Drake No. 10.
R_1	100K, 1 watt.
R_2	50K, 1 watt.

Power Supply

C_{15}, C_{16}	16 μf, 450 wv (Cornell-Dubilier KR516A).
F	3AG, 1 amp (for Littlefuse 342001 holder).
L_4	12 h, 80 ma (Thordarson 20C53).
R_3	30K, 10 watts.
R_4	2K, 25 watts (Ohmite Dividohm 0377).
R_5	5K, 25 watts (Ohmite Dividohm 0382).
S_1, S_2	SPST, toggle, 125 v, 3.5 amp.
T	300-0-300 v, 70 ma; 5 v, 2 amp; 6.3 v, 3 amp (Thordarson T22R02).

Miscellaneous

Chassis	3″ x 5″ x 7,″ aluminum (ICA 29047).
Dial	National PW-O.
Flexible coupling	National TX9.
Panel	7″ x 19,″ ⅛″ aluminum (ICA 8603RS).
VFO shield box	6″ x 6″ x 6,″ aluminum (ICA 29843).

NOTE

The appearance of a manufacturer's name following the description of a particular component should not be interpreted as a recommendation to use that particular brand. Brand names are included only to fully identify the components which are visible in the photographs. In almost all cases, equivalent components made by other manufacturers may be substituted for those shown in this parts list.

moved. Before this modification, the pigtail wire which passed through the rotor was carefully unsoldered. *If the original plans had included the use of this capacitor, the whole layout would have been reversed, i.e., the oscillator box would be located behind the left-hand side of the panel and the power supply on the right-hand side.*

Constructional Details

There are several reasons for the unusual layout; however, the two-unit construction was decided upon mainly because it permits easy wiring within the VFO box and also because the power-supply chassis provides a convenient spot for mounting the dial gear box.

The oscillator box is a standard 6 by 6 by 6-inch item, and the power-supply chassis measures 5 by 7 by 3 inches; these are fastened to a 7 by 19-inch panel. For additional strength, the oscillator box is also fastened to the power-supply chassis by means of the bakelite block shown in *Fig. 4*. The power supply is fastened to the panel with three machine screws. One of these screws (not visible in the photograph) is located under the dial; this screw is a flat-head type. Both units are mounted on the panel after wiring. Care must be exercised in mounting the oscillator box and power-supply chassis in order to obtain perfect alignment of the gear-drive and tuning-capacitor shafts.

Careful examination of the photos will show that paint on the back of the front panel has been removed from those areas where each unit makes contact with the panel. This was done to insure a good ground connection between the units and the panel.

The special attention and care which were exercised during the construction of the oscillator box have "paid off"—the VFO produces a vibration-free note. If the oscillator components are mounted and wired while the oscillator is detached from the front panel, a much better job will result.

Vibration of leads in the frequency-determining circuit can raise havoc with the note; therefore, wherever possible, ceramic standoffs and lug terminal strips are used to strengthen the lead terminations. For the same reason, bus bar has been used for a common ground.

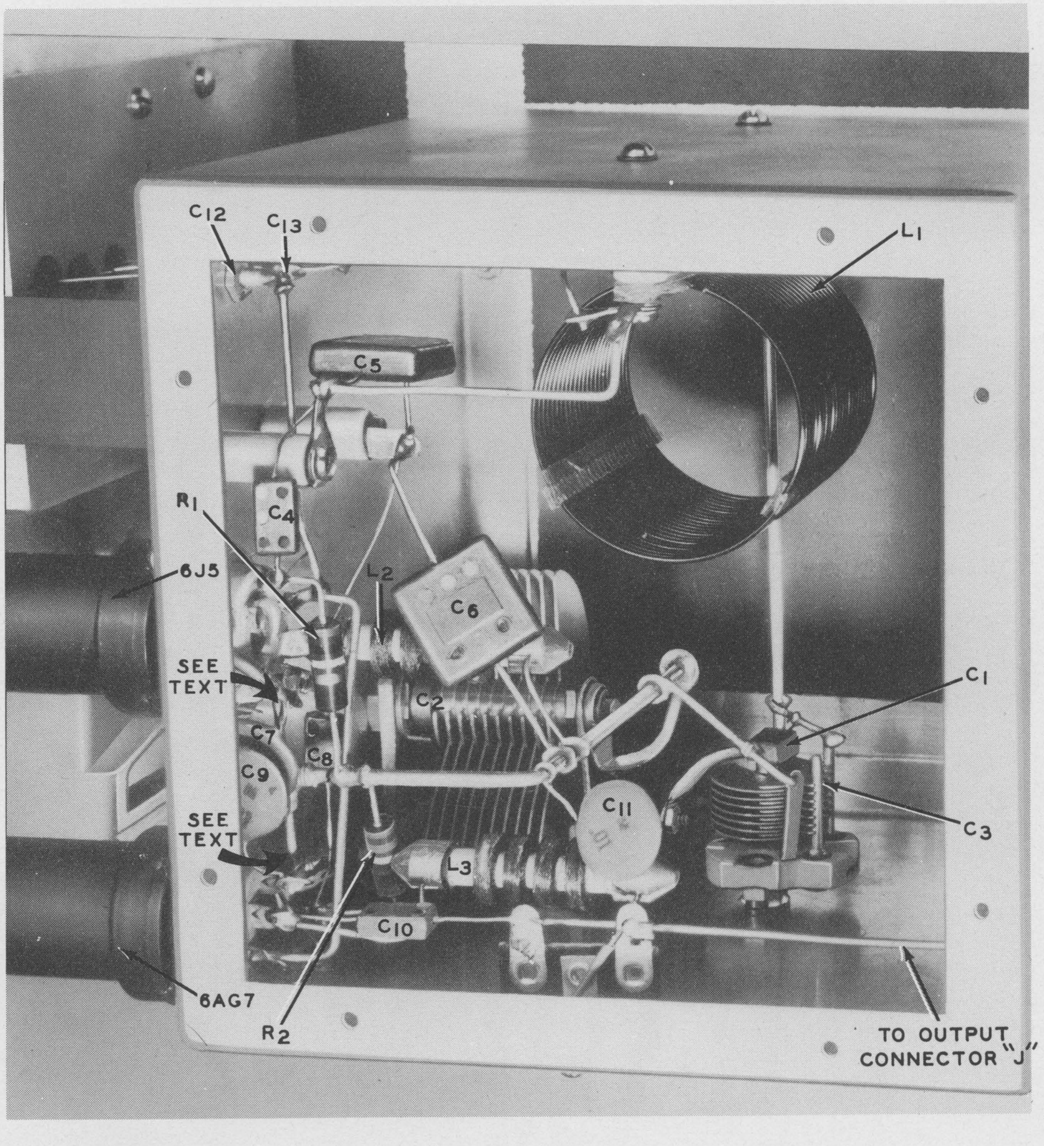
Heater and B + leads from the VFO to the power supply pass through feed-through capacitors. These capacitors are used to keep rf from feeding back to the power supply and also to prevent these connecting leads from radiating harmonics.

Line-voltage and stand-by switch connections are made through a connector on the rear apron of the power supply as shown in *Fig. 4*. This type of connector was used to conform with other connectors on the author's rack-mounted transmitter.

Wiring Procedure

A length of No. 10 bus bar serves as a common ground; it is connected to ground *only* through the rotor shaft of the tuning capacitor. All oscillator-box ground connec-

Fig. 3. Rear view of the oscillator box with the cover removed. The ground bus is bent and routed so that it functions as a common, convenient, vibrationless ground.



tions are made to this bus. The other end of this bus is supported by the heater lug of each tube socket which is to be grounded (See arrows in *Fig. 3.*). This routing of the ground bus is also clearly shown in *Fig. 3.*

The use of such a ground system eliminates ground loops which may be set up if the ground connections are made in several places on the chassis. The effect of one type of ground loop was demonstrated when an aluminum block was used (in place of the bakelite block previously mentioned) for mechanical support between oscillator box and power-supply chassis. The loop created by the addition of the aluminum block changed the calibration by approximately 20 Kc.

Connections to coil L_1, the band-set capacitor C_3, and to capacitors C_4-C_6 should be made as direct as possible and with bus bar. All other components should also be wired with short connections.

The forming and bending of the bus bar should be done before it is soldered. This procedure eliminates undue lever-action strain on lugs and terminals which would occur if bending was done after soldering one end of the bus.

Exercise reasonable care while mounting and soldering feed-through capacitors C_{12}-C_{14}. Too much pressure during the nut-tightening operation or too much heat when wires are soldered to either end of these capacitors will cause damage.

Adjustment and Calibration

Insert a milliammeter at point "X" in the circuit (See *Fig. 2.*) and connect a voltmeter from the junction of R_4 and R_5 to ground. Turn on the standby switch a half minute or so after the rectifier filaments have reached their operating temperature.

Alternately adjust resistors R_4 and R_5 until the voltmeter indicates approximately 280 volts and the milliammeter indicates approximately 10 ma. Use an insulated screwdriver to loosen and tighten the sliders on R_4 and R_5. *(Although it takes a little more time, for safety reasons it is advisable to turn the power switch off each time an adjustment is made.)* After these adjustments are made, remove the temporary meter connections. With these settings of resistors R_4 and R_5, the voltages on the oscillator and buffer tubes should be as follows:

6AG7 Plate–	280 volts	(at 20 ma)
6AG7 Screen–	150 volts	(at 15 ma)
6J5 Plate–	150 volts	

A signal source, a fairly good wavemeter, or a heterodyne frequency meter will be required to calibrate the VFO; the writer used a heterodyne frequency meter. It is preferable to do the calibrating at normal room temperature; also, it is desirable to allow the oscillator to warm up for at least 15 minutes with the stand-by switch turned on. From a cold start, the oscillator drifts about + 1 Kc; however, at the end of 15 minutes the drift is negligible.

Loosen the set screws on the dial side of the flexible coupling and, with the dial set at the first division mark, rotate C_2 to a position about one third out from the maximum-capacitance position; tighten the set screw on the coupling. With the rotor of capacitor C_3 set practically all the way out, the low-fre-

(Continued on page 7)

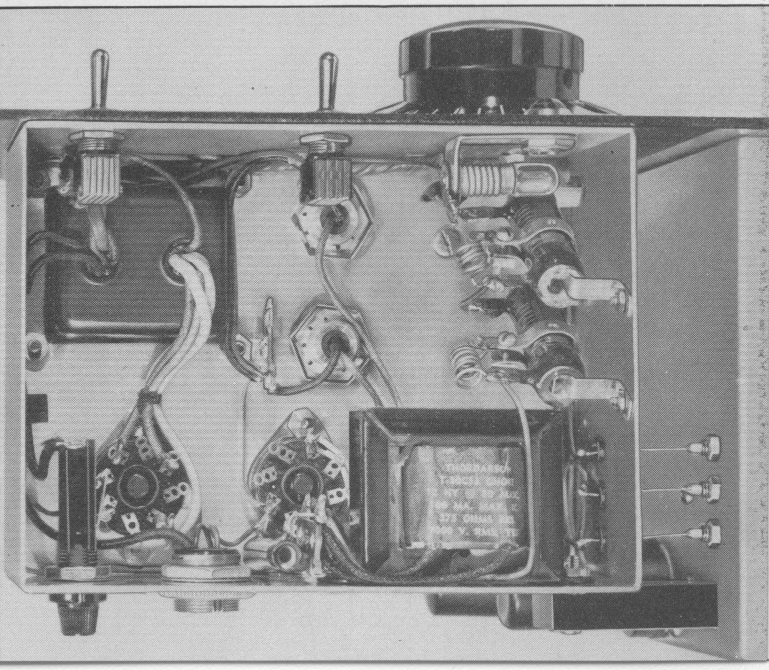


Fig. 4. Note the coiled flexible lead connecting the slider to one end of the bleeder thereby shorting out the unused resistance. Because the connection to the slider is terminated on the fixed end terminal, this arrangement prevents damage to the resistance wire by keeping the strain off the slider.

How to Determine Driver-Transformer Requirements for the Modulator

By
C. A. West,† W2IYG

After selecting the tubes and power requirements for the modulator, and the class of service for the modulator tubes and driver, the amateur is faced with the problem of selecting a suitable driver transformer for the modulator. A simple, straightforward procedure for calculating the turns ratio of the driver transformer for class AB_2 or class B service, using a few simple equations and published tube data, follows:

1. Refer to your tube manual or tube bulletin and select from the "Typical Operation" data for the driver tube (or tubes) the load resistance, R_L, for the desired value of plate voltage. For push-pull operation, the effective load resistance is given as the plate-to-plate value.

2. Determine the effective grid resistance, R_g, *of a single modulator tube* from the following approximate relation:

$R_g = \frac{E_g^2}{8P}$ where: E_g is the peak af grid-to-grid voltage (given in the published tube data).
P is the max.-signal driving power (given in the published tube data).

3. Substitute the values of R_L and R_g in the following formula:

† Tube Dept., Radio Corp. of Amercia, Harrison, N. J.

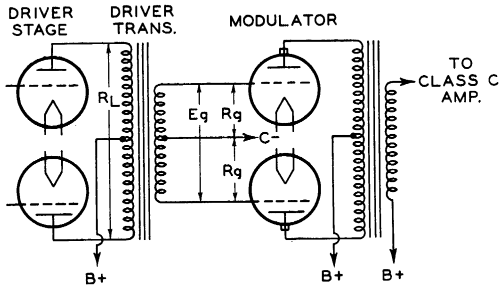


Fig. 1. For a push-pull driver stage, R_L represents the plate-to-plate load resistance. Note that R_g applies to a single modulator tube and that E_g is the grid-to-grid voltage.

$$\text{turns ratio} = \sqrt{R_L / R_g}\ .$$

If R_L is greater than R_g, the ratio is step-down; if R_L is less than R_g, the ratio is step-up. The proper impedance ratio of the entire primary winding to one-half of the secondary winding should be the same as the ratio of the load resistance, R_L, to the effective grid resistance, R_g, of a single modulator tube.

The above procedure is illustrated below:

Example. A pair of 811-A tubes have been selected to operate as class-B modulators with a plate-supply voltage of 1250 volts. The required maximum-signal driving power, P, and the peak af grid-to-grid voltage, E_g, are given in the published data (under ICAS conditions*) as 6.0 watts and 175 volts, respectively. In

* Intermittent Commercial and Amateur Service.

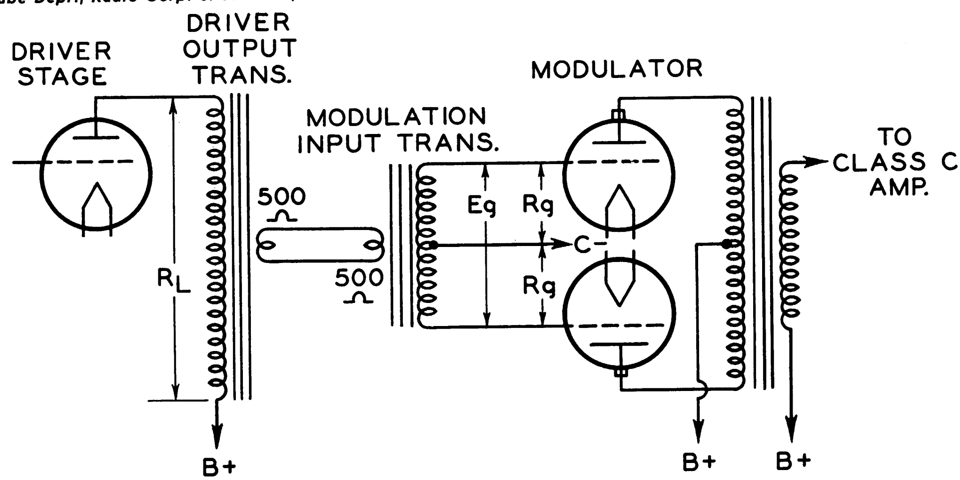


Fig. 2. If a 500-ohm line is employed between the driver stage and the modulator, 500 ohms must be substituted for R_g in the formula for the turns ratio of the driver output transformer. Similarly, 500 ohms should be substituted for R_L in the formula for the turns ratio of the modulator input transformer.

order to obtain ample driving power and to allow for circuit losses, a pair of push-pull 2A3's (operating class AB_1, with fixed bias and 300 volts on the plate) was selected to drive the modulator. The power output available from the 2A3's is approximately 15 watts.

1. The plate-to-plate effective load resistance for the push-pull 2A3's is given in the tube data as 3000 ohms.

2. The effective grid resistance of a single 811-A is

$$R_g = \frac{E_g^2}{8P} = \frac{(175)^2}{8(6)} = \underline{638 \text{ ohms.}}$$

3. The turns ratio of the driver transformer (full primary/one-half of the secondary) is

$$\sqrt{\frac{R_L}{R_g}} = \sqrt{\frac{3000}{638}} = \frac{2.16}{1} \text{ (step-down)}.$$

If a 500-ohm line is to be used between the driver stage and the modulator, the turns ratio of the driver output transformer and the modulator input transformer may be determined as follows:

1. The turns ratio of the driver output transformer (primary/secondary) is

$$\sqrt{\frac{R_L}{500}} = \sqrt{\frac{3,000}{500}} = \frac{2.45}{1} \text{ (step-down)}.$$

2. The turns ratio of the modulator input transformer (full primary/one-half of the secondary) is

$$\sqrt{\frac{500}{R_g}} = \sqrt{\frac{500}{638}} = \frac{1}{1.13} \text{ (step-up)}.$$

In addition to having the proper turns ratio, the transformer selected should be capable of handling the developed power. The use of a vari- or multi-match type transformer provides a wide range of impedance ratios as well as versatility for possible future modifications.

A PRECISION "SLICK WHISTLE" FOR 3.5 TO 4 Mc

(Continued from page 5)

quency end of the VFO tuning range (3,500 Kc) should fall near the first division mark on the dial. Several trial-and-error runs may be necessary to select the proper 180° portion of the tuning capacitor and the proper setting of C_3 to make the full 500 Kc of the 80-meter band cover the 500 dial divisions. If your station has more than one operator, it is a good idea to seal the final setting of C_3 with sealing wax immediately after the VFO is calibrated!

RF output at the output connector on the oscillator box was measured and found to be 45 volts rms with only a five-volt drop at the other end of the band. Connection to the transmitter should be made with unshielded wire of not more than two feet in length. The use of coaxial cable here is not recommended because its capacitance would shunt the high-impedance output of the buffer.*

Performance

The original calibration of this VFO was checked recently and found to be substantially as accurate as it was the day the curve was plotted. Time and again, schedules were kept on a pre-arranged frequency by returning to the same number on the VFO dial.

*** This VFO was installed in the transmitter relay rack. If the VFO is to be located on the operating table several feet from the transmitter, coax may be used if a cathode follower is inserted between the 6AG7 buffer and the coax. (See the first paragraph on pg. 3 of the June-July, 1953 issue of HAM TIPS.**

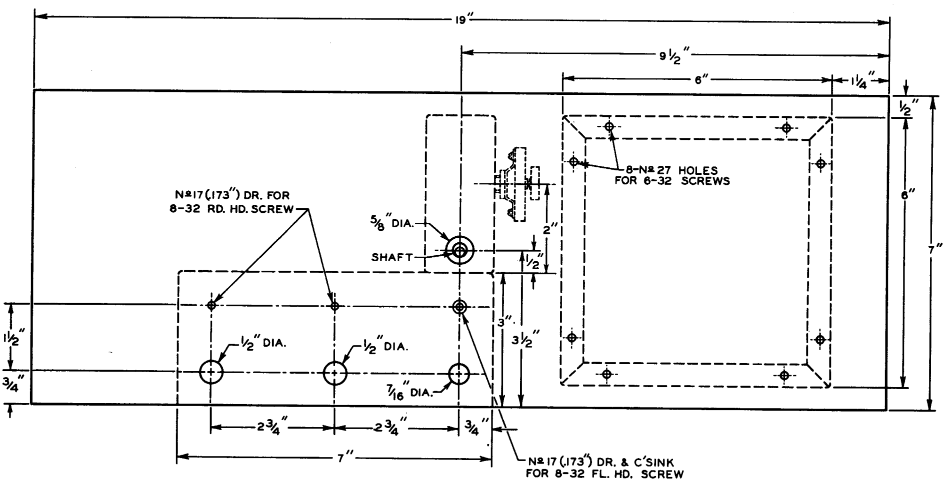


Fig. 5. Panel-layout drawing showing the location of the power-supply chassis, VFO box, and the dial gear box.

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Joseph Pastor, Jr., W2KCN
Editor

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HAM TIPS

A PUBLICATION OF THE RCA TUBE DIVISION

Vol. 14, No. 1 March-April, 1954

Design Tables for Low- and High-Pass Filters for the Reduction of TVI

By Mack Seybold,* W2RYI

Many a ham who likes to "build his own" gear will admit, without any hesitation, that he doesn't get much pleasure out of building a five-section, low-pass filter for his transmitter. And for some unknown reason, the very thought of constructing a multi-section, high-pass filter for the XYL's TV set always seems to help him muster up sufficient "negative enthusiasm" to postpone such a project!

W2RYI comes to the rescue with the following set of useful filter-design tables. As in his two previous HAM TIPS articles on filters, Mack Seybold has again made the difficult seem easy. To design a filter with the aid of the tables in this issue of HAM TIPS, all you need do is look in the tables for the type of filter you want. There you will find a schematic diagram and the actual values of L and C. No formulas are given, and no calculations are required. Armed with this data and the given sample mechanical-layout drawings, you'll surely agree that the difficult part of the job is behind you—only the bench work remains!

Novices and those hams who find this article to be their first encounter with high- and low-pass filters for TVI reduction should compare the curves in *Fig. 1* with those in *Fig. 2* to determine the basic difference in the performance of these two types of filters. A low-pass filter is placed in the transmission line between the amateur transmitter and the antenna system. It is designed to pass all signals in the amateur bands below 30 Mc, and to prevent the trans-

**RCA Tube Div., Harrison, N. J.*

Fig. 1. Theoretical response curves for all of the low-pass filters in the tables. Attenuation below 45 Mc is negligible, and harmonic radiation above 54 Mc is attenuated 60 db or better, depending upon the number of sections in the filter. Complete shielding of the transmitter and filter is required to approach the response shown in these curves.

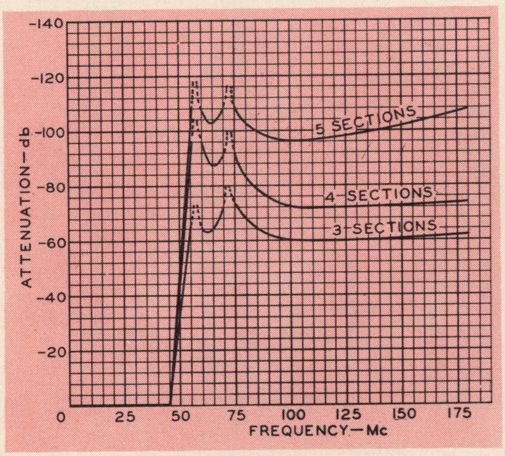
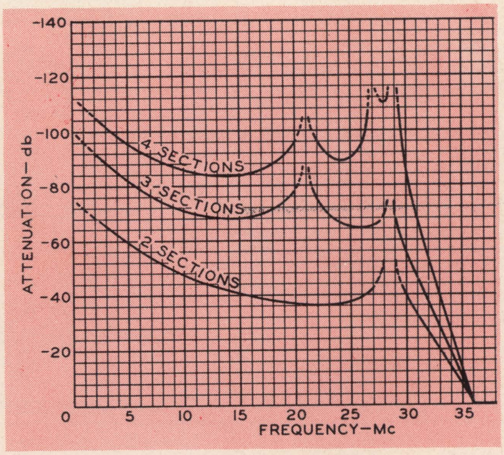


Fig. 2. Theoretical response curves for the high-pass filters in the tables. Attenuation above 36 Mc is negligible, permitting full-signal reception of television programs. Below 30 Mc, the two-, three-, and four-section filters have various attenuation peaks, and the choice for a particular installation is determined by the distance of the TV receiver from the amateur transmitter, the frequency and power of the transmitter, and the amount of filtering already present in the TV receiver.



mission of harmonics (that may be generated in the transmitter) above 45 Mc. A high-pass filter, placed in the transmission line at the "front end" of the TV receiver, does just the opposite; it passes the TV signals and attenuates all signals below 30 Mc. *Figures 1* and *2* also show the attenuation that is theoretically possible with various low- and high-pass filter structures.

Note that both series-derived filter designs and shunt-derived filters are shown in the tables. The shunt-derived, low-pass filter requires more capacitors and fewer coils than the series-derived structure.

Practical experience indicates that shunt-derived, high-pass filters have performed better than the series-derived types, probably because the signal to be attenuated comes down the feeder as a parallel standing wave and not a "transmission-line" signal; however, series-derived filters do work successfully in many installations. The latter are also easier to build and are, therefore, included in these tables.

To choose a filter design from the tables, select the configuration that matches the transmission line and produces the desired attenuation. After it has been decided what filter is best suited for the job, the values of components listed for that particular filter should be obtained from the appropriate table. The values of the components required to construct these filters are tabulated as completely-designed filters. The voltage rating for the capacitors is determined by the amount of rf to be handled. Above 200 watts input to the final amplifier of the transmitter, variable air-padder types are safest. Ceramic and mica capacitors are satisfactory for lower-powered rigs and for high-pass filters for TV receivers. Where fixed capacitors are used, select the nearest values that are commercially available and adjust the common-circuit coil inductance for the resonant frequency given in the table.

The coils for the low-pass filters can be wound with No. 12 copper wire. Directions for winding specific inductances are given in the February, 1953 issue of HAM TIPS. Coil dimensions for high-pass filters are given in the article entitled, "Design and Application of High-Pass Filters," in the Fall, 1950 issue of HAM TIPS.

Isolation of the various components (inductively and capacitively) is necessary to achieve maximum attenuation from both low-pass and high-pass filters. This isolation is accomplished by shielding as shown in *Figures 3* and *4*. If the number of sections in the desired filter is less than five for a low-pass filter or four for a high-pass filter (the maximum number in the tables) and you feel that you may later wish to increase the number of sections, choose a shield box large enough to provide an extra compartment.

Other filter configurations and further details on construction are given in the articles mentioned above and in, "The Design of Low-Pass Filters," *QST*, Dec., 1949.

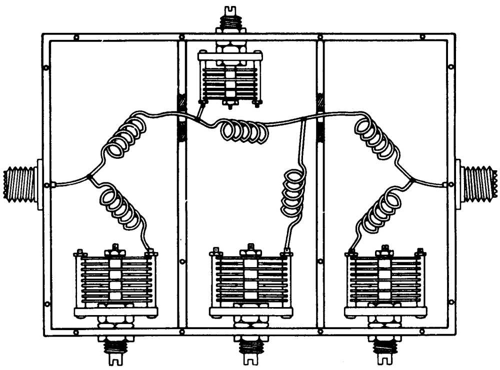


Fig. 3. Top view showing the arrangement of the parts in a three-section, series-derived, low-pass filter. The top and bottom plates of the shield box are not shown. When these plates are bolted into position, the shield box completely encloses the components. The shield box should be bolted to the transmitter cabinet where the transmission line emerges.

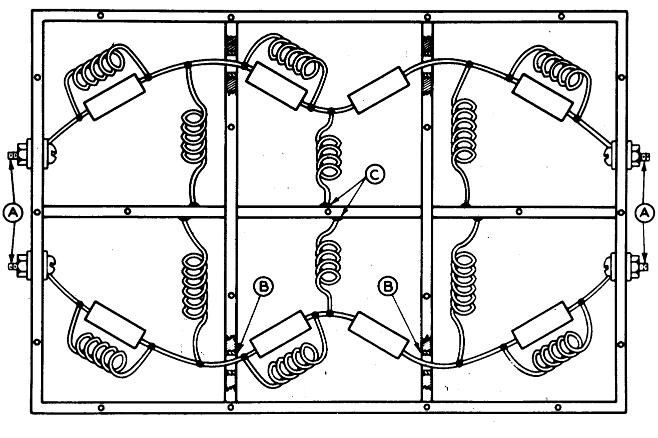
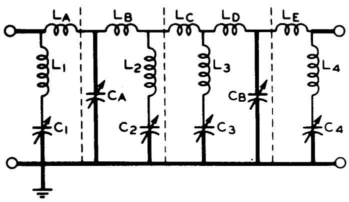
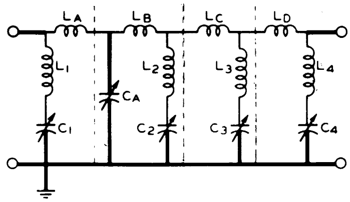
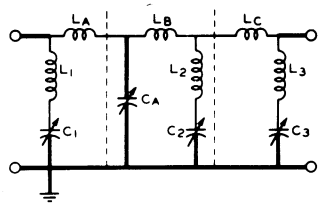


Fig. 4. Top view of a three-section, shunt-derived, balanced-line, high-pass filter. Insulated screws (A) can be used for connection to the transmission line, and insulated bushings (B) carry the connections between shielded sections. Grounded components are connected directly to the shield walls (C). The shield box should be bolted (or connected with a short copper strap) to the TV receiver chassis. Similar shielding is recommended for balanced-line, low-pass filters. High-pass filters will work without shielding, but additional sections are required to make up for the signal passed on from section to section by stray coupling.

Table I
Low-Pass Filters, Series Derived, for Coax Line (45-Mc Cut-off)







5 Sections

	Trans. Line 52 (Ohms)	Trans. Line 72 (Ohms)	Resonant Freq. (Mc)
C_1	41	29	56
L_1	0.196	0.275	
C_2	87	62	58
L_2	0.087	0.122	
C_3	106	76	71
L_3	0.048	0.067	
C_4	41	29	57
L_4	0.196	0.275	
C_A	136	97	
C_B	136	97	
L_A	0.294	0.412	
L_B	0.301	0.422	
L_C	0.261	0.365	
L_D	0.328	0.460	
L_E	0.294	0.412	

4 Sections

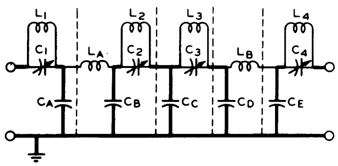
	Trans. Line 52 (Ohms)	Trans. Line 72 (Ohms)	Resonant Freq. (Mc)
C_1	41	29	56
L_1	0.196	0.275	
C_2	87	62	58
L_2	0.087	0.122	
C_3	106	76	71
L_3	0.048	0.067	
C_4	41	29	57
L_4	0.196	0.275	
C_A	136	97	
—	—	—	
L_A	0.294	0.412	
L_B	0.301	0.422	
L_C	0.261	0.365	
L_D	0.254	0.356	
—	—	—	

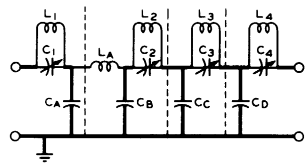
3 Sections

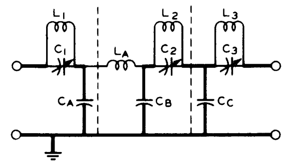
	Trans. Line 52 (Ohms)	Trans. Line 72 (Ohms)	Resonant Freq. (Mc)
C_1	41	29	56
L_1	0.196	0.275	
C_2	106	76	71
L_2	0.048	0.067	
C_3	41	29	57
L_3	0.196	0.275	
—	—	—	
—	—	—	
C_A	136	97	
—	—	—	
L_A	0.294	0.412	
L_B	0.328	0.460	
L_C	0.254	0.356	
—	—	—	
—	—	—	

NOTE. In tables I through VII, C is in $\mu\mu$f and L is in μh. The heavy lines represent short, low-inductance paths connecting the components. The dashed lines are shield compartment walls. (An unshielded low-pass filter is undesirable because harmonics may be radiated from the first or second section.)

Table II
Low-Pass Filters, Shunt Derived, for Coax Lines (45-Mc Cut-off)







5 Sections

	Trans. Line 52 (Ohms)	Trans. Line 72 (Ohms)	Resonant Freq. (Mc)
C_1	73	53	56
L_1	0.11	0.154	
C_2	17	12	71
L_2	0.288	0.40	
C_3	33	24	58
L_3	0.231	0.32	
C_4	73	53	57
L_4	0.11	0.154	
C_A	109	79	
C_B	124	90	
C_C	100	72	
C_D	112	81	
C_E	109	79	
L_A	0.368	0.510	
L_B	0.368	0.510	

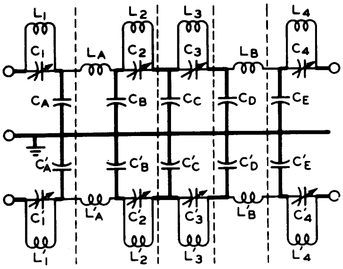
4 Sections

	Trans. Line 52 (Ohms)	Trans. Line 72 (Ohms)	Resonant Freq. (Mc)
C_1	73	53	56
L_1	0.11	0.154	
C_2	17	12	71
L_2	0.288	0.40	
C_3	33	24	58
L_3	0.231	0.32	
C_4	73	53	57
L_4	0.11	0.154	
C_A	109	79	
C_B	124	90	
C_C	100	72	
C_D	85	61	
—	—	—	
L_A	0.368	0.510	
—	—	—	

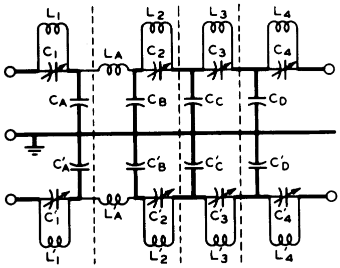
3 Sections

	Trans. Line 52 (Ohms)	Trans. Line 72 (Ohms)	Resonant Freq. (Mc)
C_1	73	53	56
L_1	0.11	0.154	
C_2	17	12	71
L_2	0.288	0.40	
C_3	73	53	57
L_3	0.11	0.154	
—	—	—	
—	—	—	
C_A	109	79	
C_B	124	90	
C_C	97	70	
—	—	—	
—	—	—	
L_A	0.368	0.510	
—	—	—	

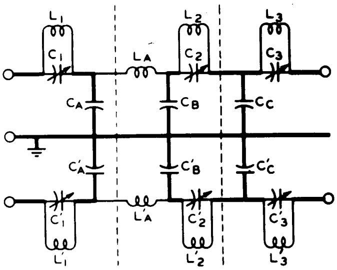
Table III Low-Pass Filters, Shunt Derived, for Balanced Line (45-Mc Cut-off)



5 Sections



4 Sections



3 Sections

5 Sections

	Trans. Line (Ohms) 100	150	300	600*	Resonant Freq. (Mc)
C_1,C'_1	75	50	25	12.5	56
L_1,L'_1	0.107	0.16	0.32	0.635	
C_2,C'_2	18	12	6	3	71
L_2,L'_2	0.275	0.415	0.83	1.66	
C_3,C'_3	33	22	11	5.5	58
L_3,L'_3	0.225	0.34	0.66	1.33	
C_4,C'_4	75	50	25	12.5	57
L_4,L'_4	0.107	0.16	0.32	0.635	
C_A,C'_A	114	76	38	19	
C_B,C'_B	129	86	43	22	
C_C,C'_C	105	70	35	18	
C_D,C'_D	117	78	39	19	
C_E,C'_E	114	76	38	19	
L_A,L'_A	0.35	0.53	1.06	2.12	
L_B,L'_B	0.35	0.53	1.06	2.12	

4 Sections

	Trans. Line (Ohms) 100	150	300	600*	Resonant Freq. (Mc)
C_1,C'_1	75	50	25	12.5	56
L_1,L'_1	0.107	0.16	0.32	0.635	
C_2,C'_2	18	12	6	3	71
L_2,L'_2	0.275	0.415	0.83	1.66	
C_3,C'_3	33	22	11	5.5	58
L_3,L'_3	0.225	0.34	0.66	1.33	
C_4,C'_4	75	50	25	12.5	57
L_4,L'_4	0.107	0.16	0.32	0.635	
C_A,C'_A	114	76	38	19	
C_B,C'_B	129	86	43	22	
C_C,C'_C	105	70	35	18	
C_D,C'_D	87	58	29	15	
—	—	—	—	—	
L_A,L'_A	0.35	0.53	1.06	2.12	
—	—	—	—	—	

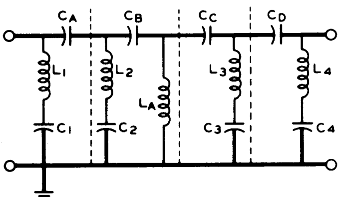
3 Sections

	Trans. Line (Ohms) 100	150	300	600*	Resonant Freq. (Mc)
C_1,C'_1	75	50	25	12.5	56
L_1,L'_1	0.107	0.16	0.32	0.635	
C_2,C'_2	18	12	6	3	71
L_2,L'_2	0.275	0.415	0.83	1.66	
C_3,C'_3	75	50	25	12.5	57
L_3,L'_3	0.107	0.16	0.32	0.635	
—	—	—	—	—	
—	—	—	—	—	
C_A,C'_A	114	76	38	19	
C_B,C'_B	129	86	43	22	
C_C,C'_C	102	68	34	17	
—	—	—	—	—	
—	—	—	—	—	
L_A,L'_A	0.35	0.53	1.06	2.12	
—	—	—	—	—	

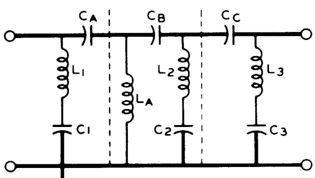
*600-ohm filters designed to cut off at 45 Mc are difficult to construct because of the low capacitance and high inductance of the components. Coils with low distributed capacitance must be employed, and care must be taken to mount the resonant sections away from shield walls.

Table IV

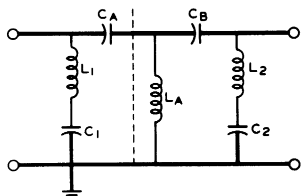
High-Pass Filters, Series Derived, for Coax Lines (36-Mc Cut-off)



4 Sections



3 Sections



2 Sections

4 Sections

	Trans. Line (Ohms) 52	72	Resonant Freq. (Mc)
C_1	79	57	29
L_1	0.38	0.53	
C_2	200	145	27
L_2	0.17	0.24	
C_3	400	290	21
L_3	0.14	0.20	
C_4	79	57	28.5
L_4	0.38	0.53	
C_A	66	48	
C_B	51	37	
C_C	47	34	
C_D	60	43	
L_A	0.11	0.16	

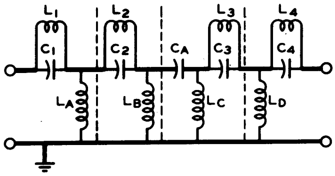
3 Sections

	Trans. Line (Ohms) 52	72	Resonant Freq. (Mc)
C_1	79	57	29
L_1	0.38	0.53	
C_2	400	290	21
L_2	0.14	0.20	
C_3	79	57	28.5
L_3	0.38	0.53	
—	—	—	
—	—	—	
C_A	53	38	
C_B	47	34	
C_C	60	43	
—	—	—	
L_A	0.11	0.16	

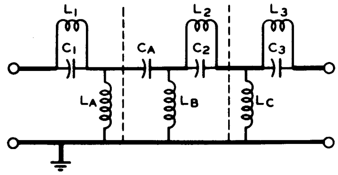
2 Sections

	Trans. Line (Ohms) 52	72	Resonant Freq. (Mc)
C_1	79	57	29
L_1	0.38	0.53	
C_2	79	57	28.5
L_2	0.38	0.53	
—	—	—	
—	—	—	
—	—	—	
—	—	—	
C_A	53	38	
C_B	53	38	
—	—	—	
—	—	—	
L_A	0.11	0.16	

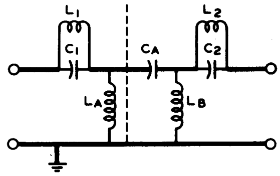
Table V
High-Pass Filters, Shunt Derived, for Coax Lines (36-Mc Cut-off)



4 Sections



3 Sections



2 Sections

4 Sections

	Trans. Line 52 (Ohms)	72	Resonant Freq. (Mc)
C_1	141	102	29
L_1	0.21	0.30	
C_2	63	46	27
L_2	0.55	0.77	
C_3	52	38	21
L_3	1.09	1.51	
C_4	141	102	28.5
L_4	0.21	0.30	
L_A	0.18	0.25	
L_B	0.14	0.19	
L_C	0.12	0.17	
L_D	0.16	0.23	
C_A	42	30	

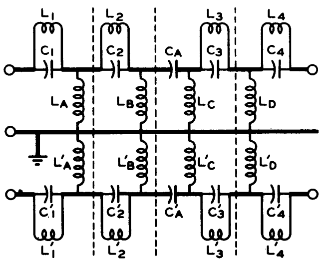
3 Sections

	Trans. Line 52 (Ohms)	72	Resonant Freq. (Mc)
C_1	141	102	29
L_1	0.21	0.30	
C_2	52	38	21
L_2	1.09	1.51	
C_3	141	102	28.5
L_3	0.21	0.30	
—	—	—	
—	—	—	
L_A	0.14	0.20	
L_B	0.12	0.17	
L_C	0.16	0.23	
—	—	—	
C_A	42	30	

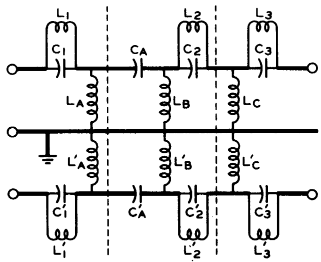
2 Sections

	Trans. Line 52 (Ohms)	72	Resonant Freq. (Mc)
C_1	141	102	29
L_1	0.21	0.30	
C_2	141	102	28.5
L_2	0.21	0.30	
—	—	—	
—	—	—	
—	—	—	
—	—	—	
L_A	0.14	0.20	
L_B	0.14	0.20	
—	—	—	
—	—	—	
C_A	42	30	

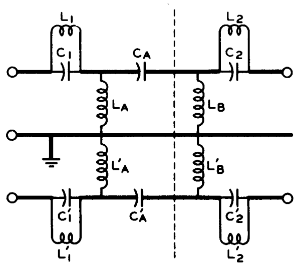
Table VI
High-Pass Filters, Shunt Derived, for Balanced Lines (36-Mc Cut-off)



4 Sections



3 Sections



2 Sections

4 Sections

	Trans. Line 100	150 (Ohms)	300	Resonant Freq. (Mc)
C_1,C'_1	147	98	48.8	29
L_1,L'_1	0.21	0.31	0.62	
C_2,C'_2	66	44	22	27
L_2,L'_2	0.53	0.8	1.6	
C_3,C'_3	55	36	18.2	21
L_3,L'_3	1.05	1.57	3.15	
C_4,C'_4	147	98	48.8	28.5
L_4,L'_4	0.21	0.31	0.62	
L_A,L'_A	0.17	0.26	0.52	
L_B,L'_B	0.13	0.20	0.39	
L_C,L'_C	0.12	0.18	0.36	
L_D,L'_D	0.16	0.24	0.47	
C_A,C'_A	44	29	14.7	

3 Sections

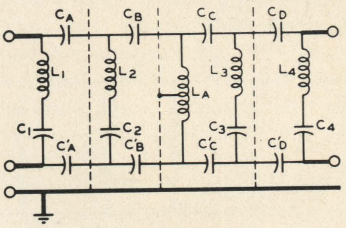
	Trans. Line 100	150 (Ohms)	300	Resonant Freq. (Mc)
C_1,C'_1	147	98	48.8	29
L_1,L'_1	0.21	0.31	0.62	
C_2,C'_2	55	36	18.2	21
L_2,L'_2	1.05	1.57	3.15	
C_3,C'_3	147	98	48.8	28.5
L_3,L'_3	0.21	0.31	0.62	
—	—	—	—	
—	—	—	—	
L_A,L'_A	0.14	0.20	0.41	
L_B,L'_B	0.12	0.18	0.36	
L_C,L'_C	0.16	0.24	0.47	
—	—	—	—	
C_A,C'_A	44	29	14.7	

2 Sections

	Trans. Line 100	150 (Ohms)	300	Resonant Freq. (Mc)
C_1,C'_1	147	98	48.8	29
L_1,L'_1	0.21	0.31	0.62	
C_2,C'_2	147	98	48.8	28.5
L_2,L'_2	0.21	0.31	0.62	
—	—	—	—	
—	—	—	—	
—	—	—	—	
L_A,L'_A	0.14	0.20	0.41	
L_B,L'_B	0.14	0.20	0.41	
—	—	—	—	
—	—	—	—	
C_A,C'_A	44	29	14.7	

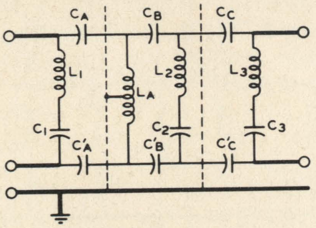
Table VII

High-Pass Filters, Series Derived, for Balanced Line (36-Mc Cut-off)



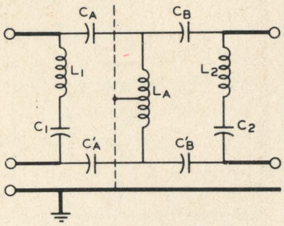
4 Sections

	Trans. Line 100 (Ohms)	150	300	Resonant Freq. (Mc)
C_1	41	27.4	13.7	29
L_1	0.73	1.1	2.2	
C_2	104	69.6	34.8	27
L_2	0.33	0.5	1.0	
C_3	210	140	70	21
L_3	0.27	0.41	0.818	
C_4	41	27.4	13.7	28.5
L_4	0.73	1.1	2.2	
C_A, C'_A	69	46	23	
C_B, C'_B	53	35.2	17.6	
C_C, C'_C	49	32.4	16.2	
C_D, C'_D	62	41.6	20.8	
L_A	0.22	0.33	0.66	



3 Sections

	Trans. Line 100 (Ohms)	150	300	Resonant Freq. (Mc)
C_1	41	27.4	13.7	29
L_1	0.73	1.1	2.2	
C_2	210	140	70	21
L_2	0.27	0.41	0.818	
C_3	41	27.4	13.7	28.5
L_3	0.73	1.1	2.2	
—	—	—	—	
—	—	—	—	
C_A, C'_A	55	37	18.4	
C_B, C'_B	49	32.4	16.2	
C_C, C'_C	62	41.6	20.8	
—	—	—	—	
L_A	0.22	0.33	0.66	



2 Sections

	Trans. Line 100 (Ohms)	150	300	Resonant Freq. (Mc)
C_1	41	27.4	13.7	29
L_1	0.73	1.1	2.2	
C_2	41	27.4	13.7	28.5
L_2	0.73	1.1	2.2	
—	—	—	—	
—	—	—	—	
—	—	—	—	
—	—	—	—	
C_A, C'_A	55	37	18.4	
C_B, C'_B	55	37	18.4	
—	—	—	—	
—	—	—	—	
L_A	0.22	0.33	0.66	

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HAM TIPS

RCA

A PUBLICATION OF THE RCA TUBE DIVISION

Vol. 14, No. 2 July-August, 1954

Components for Pi-Coupled Amplifiers

By

Mack Seybold,* W2RYI

Most of the references on this subject present data for the determination of values of the components for pi-coupled amplifiers in terms of curves or formulas. To simplify the design procedure for the amateur, W2RYI has compiled this data in easy-to-use tabular form.

The use of a pi network to couple the plate of an rf amplifier tube to the antenna provides several advantages over the use of a conventional parallel-tuned, inductively-coupled tank circuit. The ease with which a multiband transmitter employing a pi-network tank circuit with rotary or tapped coils can be operated on several bands, in addition to its harmonic-attenuation feature, has made this circuit appealing to designers of amateur transmitters. The circuit is also popular because front-panel controls can be used to compensate for reasonably large variations in transmission-line reactance.

The function of the pi network is to match a transmission line having relatively low characteristic impedance to the plate of a tube which must "see" a relatively high resistive load to produce optimum power output. *Table I* lists the estimated plate loads for the various operating conditions of several popular tubes used in amateur transmitters. To determine the plate load for a given tube type, refer to *Table I* and select the operating condition that most closely fits your requirements; the estimated plate-load value for that operating condition is given in the last column in the table. The exact load for tubes not listed in *Table I* can be determined from a set of complicated calculations; however, a good approximation can be made with the formula:

$$\text{Estimated Plate Load (ohms)} = \frac{E_b}{2I_b}$$

where E_b is the plate supply voltage, and I_b is the dc plate current in ma.

The estimated plate load is then used as the key to *Table II*. This table lists the actual values of the pi-network components for the estimated plate loads; *Fig. 1* shows the location of these components in the circuit.

Example

An RCA 6146 is to be used in a 7-Mc, cw transmitter with 750 volts on the plate, and the signal is to be fed to a 50-ohm, coaxial line. *Table I* shows the estimated plate load to be 3,100 ohms. As shown in the 3,000-ohm column of *Table II*, 7-Mc operation requires 90 $\mu\mu$f for C_1, 6.2 μh for L, and 700 $\mu\mu$f for C_2.

When a 50-ohm, non-reactive load is applied to the coax output connector, optimum loading at 7 Mc will occur with components

*RCA Tube Div., Harrison, N. J.

approximating the above values. In a practical transmitter, a capacitor of 1,000 $\mu\mu$f should be used for C_2 so that the loading can be reduced when desirable, and so that compensation can be made for variations in antenna reactance. Capacitor C_1 should be capable of tuning through resonance at 7 Mc; all variations in reactance considered, a capacitance of 150 $\mu\mu$f would be considered to be a safe design value for C_1.

Recommendations

Design and constructional details for pi-coupled finals are amply covered in the articles listed in the accompanying bibliography. These articles should be examined thoroughly for ideas and suggestions before construction is begun.

In addition to the many valuable suggestions in the literature on the design of multi-band rigs using pi-coupled finals, there are two precautions to be observed: (1) The driver should be a straight-through amplifier employing a conventional tuned tank circuit. (2) The final amplifier should not be operated as a doubler. These recommendations are important because the pi-coupled amplifier, in addition to attenuating harmonics effectively, will pass signals at frequencies below the fundamental more readily than an amplifier employing a parallel-resonant plate circuit. If the low-frequency signals from preceding multiplier stages are not permitted to reach the control grid of a pi-coupled final amplifier, successful operation will be assured.

Table I
Estimated Plate Loads for Typical Operating Conditions

Tube Type	Service	Emission	E_b volts	E_{c_2} volts	I_b ma	P_o watts	Plate Load ohms
813	ICAS	CW	2,250	400	220	375	5,100
	CCS	CW	2,000	400	180	275	5,500
	CCS	CW	1,500	300	180	210	4,200
	ICAS	Phone	2,000	350	200	300	5,000
	CCS	Phone	1,600	300	150	180	5,300
813's (Parallel)	ICAS	CW	2,250	400	440	750	2,600
	ICAS	Phone	2,000	350	400	600	2,500
807	ICAS	CW	750	250	100	54	3,700
	CCS	CW	600	250	100	40	3,000
	CCS	CW	500	250	100	32	2,500
	ICAS	Phone	600	300	100	44	3,000
	CCS	Phone	475	250	83	28	2,900
807's (Parallel)	ICAS	CW	750	250	200	108	1,900
	ICAS	Phone	600	300	200	88	1,500
6146	ICAS	CW	750	160	120	70	3,100
	ICAS	CW	600	180	150	66	2,000
	CCS	CW	600	150	112	52	2,600
	ICAS	Phone	600	150	112	52	2,600
	CCS	Phone	475	135	94	34	2,600
812-A*	ICAS	CW	1,500	—	173	190	4,300
	CCS	CW	1,250	—	140	130	4,500
	ICAS	Phone	1,250	—	140	130	4,500
	CCS	Phone	1,000	—	115	85	4,300
4-65A**	CCS	CW	1,500	250	150	170	5,000
	CCS	CW	600	250	140	54	2,100
	CCS	Phone	1,500	250	120	145	6,200
	CCS	Phone	600	250	117	50	2,500
4-125A/4D21	CCS	CW	2,500	350	200	375	6,200
	CCS	CW	2,000	350	200	275	5,000
	CCS	Phone	2,000	350	150	225	8,200
	CCS	Phone	2,500	350	152	300	6,700
4-250/5D22	CCS	CW	3,000	500	345	800	4,300
	CCS	CW	2,500	500	300	575	4,100
	CCS	Phone	3,000	400	225	510	6,700
	CCS	Phone	2,500	400	200	375	6,200
2E26	ICAS	CW	600	185	66	27	4,500
	CCS	CW	500	185	60	20	4,200
	ICAS	Phone	500	180	54	18	4,600
	CCS	Phone	400	160	50	13.5	4,600

*Grid Neutralization

**Typical operating conditions at higher plate voltages are published, but plate impedances are too high for convenient pi-network operation.

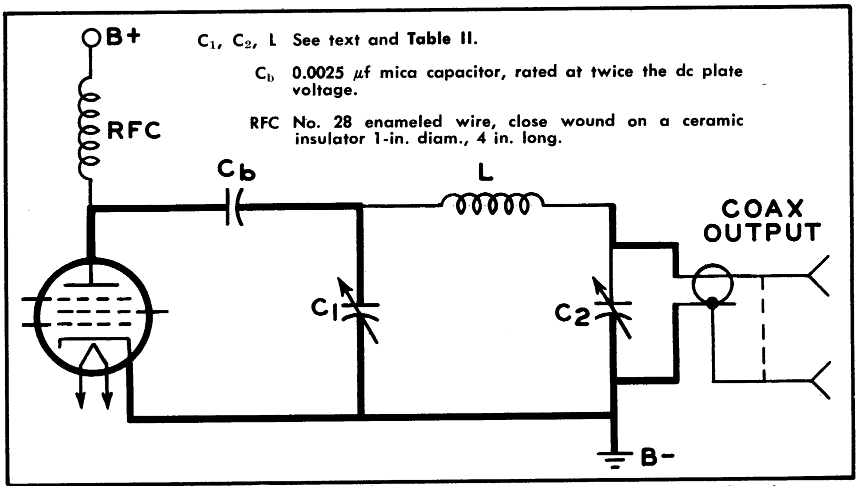

Fig. 1. Plate circuit for the pi-coupled final. Mount the components so that the connections and "chassis" paths, shown as heavy lines, will be as short as possible.

Table II Components for Pi-Coupled Final Amplifiers*

Estimated Plate Load (ohms)		1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	6,000*	NOTES
C_1 in $\mu\mu f$,	3.5 Mc	520	360	280	210	180	155	135	120	110	90	The actual capacitance setting for C_1 equals the value in this table minus the published tube output capacitance. Air gap approx. 10 mils/100 v E_b.
	7	260	180	140	105	90	76	68	60	56	45	
	14	130	90	70	52	45	38	34	30	28	23	
	21	85	60	47	35	31	25	23	20	19	15	
	28	65	45	35	26	23	19	17	15	14	11	
L in μh,	3.5 Mc	4.5	6.5	8.5	10.5	12.5	14	15.5	18	20	25	Inductance values are for a 50-ohm load. For a 70-ohm load, values are approx. 3% higher.
	7	2.2	3.2	4.2	5.2	6.2	7	7.8	9	10	12.5	
	14	1.1	1.6	2.1	2.6	3.1	3.5	3.9	4.5	5	6.2	
	21	0.73	1.08	1.38	1.7	2.05	2.3	2.6	3	3.3	4.1	
	28	0.55	0.8	1.05	1.28	1.55	1.7	1.95	2.25	2.5	3.1	
C_2 in $\mu\mu f$,	3.5 Mc	2,400	2,100	1,800	1,550	1,400	1,250	1,100	1,000	900	700	For 50-ohm transmission line. Air gap for C_2 is approx. 1 mil/100 v E_b.
	7	1,200	1,060	900	760	700	630	560	500	460	350	
	14	600	530	450	380	350	320	280	250	230	175	
	21	400	350	300	250	230	210	185	165	155	120	
	28	300	265	225	190	175	160	140	125	115	90	
C_2 in $\mu\mu f$,	3.5 Mc	1,800	1,500	1,300	1,100	1,000	900	800	720	640	500	For 70-ohm transmission line.
	7	900	750	650	560	500	450	400	360	320	250	
	14	450	370	320	280	250	220	200	180	160	125	
	21	300	250	215	190	170	145	130	120	110	85	
	28	225	185	160	140	125	110	100	90	80	65	

* Values given are approximations. All components shown in Table II are for a Q of 12. For other values of Q, use $\frac{Q_a}{Q_b} = \frac{C_a}{C_b}$ and $\frac{Q_a}{Q_b} = \frac{L_b}{L_a}$. When the estimated plate load is higher than 5,000 ohms, it is recommended that the components be selected for a circuit Q between 20 and 30.

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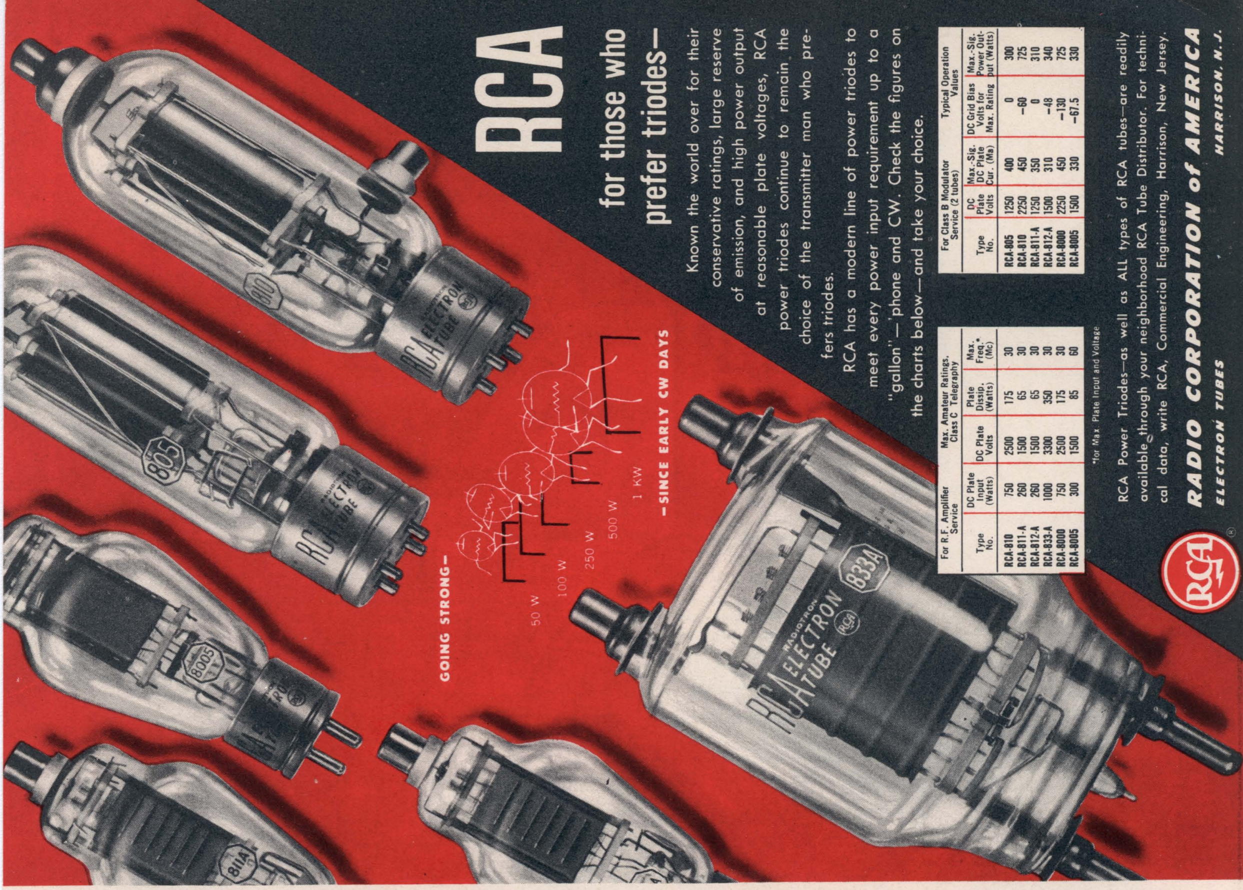
8. "Simplified Pi-Network Solutions," Hoefer, CQ, Nov., 1953.

NEW RCA TYPE 80

The RCA type 80 full-wave vacuum rectifier was recently changed over from a size ST-14 bulb to a T-9 bulb, like that used for the 5Y3-GT. This was done in order to utilize RCA's modern tube manufacturing techniques and equipment more effectively, despite declining replacement demand for the type 80.

The basing connections as well as all electrical characteristics and ratings remain unchanged in the new design. Since the new bulb size is smaller than the old one, this new type 80 can be installed in all sockets where the old 80 was used.



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HAM TIPS

A PUBLICATION OF THE RCA TUBE DIVISION

Vol. 14, No. 3 December, 1954

Determination of Typical Operating Conditions for RCA Tubes Used as Linear RF Power Amplifiers

By A. P. Sweet*

During the past several years, there has been a tremendous increase in the use of single-sideband, suppressed-carrier transmission in amateur-radio radiotelephony. This type of transmission offers several advantages over the widely-used amplitude modulation methods. These advantages include reduced band-width and the elimination of heterodyne-interference problems. More useful power can be obtained with the same tubes and power supplies or, conversely, smaller tubes and power supplies can be used to deliver the same useful power.

With high-level amplitude modulation, a carrier and two groups of sideband frequencies are generated. The total power in the two sidebands at 100 per cent modulation is equal to one half of the carrier power. Thus, for every 100 watts of total transmitted power, 67 watts is in the carrier and 16.5 watts is in each sideband. Yet, one sideband contains all of the necessary intelligence for communication (provided certain receiver requirements are met).

Half the Bandwidth

Single-sideband, suppressed-carrier transmission utilizes only one sideband. By the elimination of the other sideband, the bandwidth is cut in half. By suppression of the carrier, heterodyne interference is eliminated. Only 16.5 watts of power is required to convey the same intelligence. Conversely, if the original 100 watts of power is transmitted in a single side-band, six times the former useful power will be obtained.

The literature contains considerable information on various methods of generating single-sideband, suppressed-carrier signals. However, little information is available on the choice of tubes for amplifying these signals and the methods of calculating typical operating conditions for these tubes.

Linear RF Amplifiers

Single-sideband signals must be amplified by linear rf amplifiers. These amplifiers are identical to af power amplifiers except that resonant tank circuits are used in the grid and plate circuits instead of audio-frequency transformers. Consequently, the tube manufacturer's ratings for af power amplifier and modulator service for class A, AB_1, AB_2, and class B and typical operating conditions will apply, provided the tube is also capable of operating at the higher frequencies involved. The same derating factors for plate voltage and input versus frequency shown by the manufacturer for class-C telegraphy ratings should be applied to single-sideband operation at the frequencies where they become applicable.

Because the tank circuits act as energy-storage systems, it is not necessary (as in case of audio work) to use two tubes in push-pull in class-AB or class-B, linear, rf amplifiers. However, if only one tube is used, the rf harmonics will be higher thereby making the TVI problems more severe.

Although the manufacturer's ratings are based on 100 per cent modulation with sine-wave signals, normal voice modulation reaches this condition only on the peaks of modulation. The ICAS ratings shown by RCA have

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* *Power Tube Engineering, Lancaster, Pa.*

taken this factor into account. Consequently, no attempt should be made to operate above these maximum ratings. Such operation will result in shorter tube life and the possibility of early tube damage during transmitter adjustment or unexpected overloads such as microphone "howl."

Since only rf power amplifiers are being considered, class A operation will not be discussed further. Of the remaining classes, AB_1 operation with tetrodes or pentodes is the simplest since only the plate- and screen-voltage supplies require good regulation.

Table I includes the maximum ratings and typical operating conditions for several RCA tubes used as linear rf power amplifiers. If it is desired to operate at conditions other than those given, typical conditions can be calculated by means of the following procedure:

1. Make sure E_b is within tube ratings.
2. Refer to the published curves. On the average plate characteristics curves, select a point on the zero grid-voltage curve near the "knee," and record i'_b,* and e_{bmin}; from the average screen-grid characteristics curves, determine i'_{c2} for this point.
   (E_{c2} equals the value shown for the curves used.)
3. Calculate I_{bms}: $I_{bms} = i'_b/3$.
4. Calculate PD:
   $$PD = \frac{I_{bms}}{4}(E_b + 3e_{bmin}).$$
5. Calculate SI: $SI = E_{c2}i'_{c2}/4.$
6. Calculate PI: $PI = E_b I_{bms}$.
7. Check the values found in steps 4, 5, and 6 to determine whether they are within tube ratings. Normally, they will be within ratings for AB_1 operation. If they are not, a lower value of i'_b (either in the negative-grid region or at a lower screen voltage) must be selected and steps 2 through 7 repeated.
8. Calculate PO: $PO = PI - PD$.
9. Calculate I_{bo}: $I_{bo} = I_{bms} / 5$.
10. E_{c1} can now be found on the plate characteristics curves as the grid voltage where the plate voltage is E_b and the plate current is I_{bo}.
11. $E'_g = [E_{c1}] + e_{cm}$.
    This value of E_g is the absolute value of E_{c1} (the brackets mean ignore the sign) plus the algebraic value of e_{cm} (include the sign). If the original point in step 2 was selected on the zero grid-voltage curve, then e_{cm} is equal to zero and
    $$E'_g = [E_{c1}].$$
12. Calculate I_{c2}: $I_{c2} = i'_{c2}/4$.
13. Calculate DP: $DP = \frac{E'_g i'_{c2}}{2}$ (for AB_1 operation, $i'_{c1} = O$ so DP is zero).

*

E_b	*Dc plate voltage.*
e_{bmin}	*Minimum plate voltage for the required peak current (from the characteristics curves).*
E_{c2}	*Dc screen voltage.*
E_{c1}	*Dc control grid voltage.*
e_{cm}	*Maximum grid-voltage drive to obtain the required peak plate current at a given minimum plate voltage.*
E'_g	*Peak value of grid-voltage swing.*
I_{bms}	*Maximum-signal, dc plate current.*
I_{bo}	*Zero-signal, dc plate current.*
i'_b	*Instantaneous peak plate current.*
I_{c2}	*Maximum-signal, dc screen current.*
i'_{c2}	*Instantaneous peak screen current.*
i'_{c1}	*Instantaneous peak grid current.*
PD	*Plate dissipation at maximum signal.*
PI	*Plate power input at maximum signal.*
PO	*Power output at maximum signal.*
DP	*Driving power at maximum signal.*
SI	*Screen input at maximum signal.*

Class-AB_2 Tetrode or Class-B Triode Operation

Class-AB_2 tetrode and class-B triode operation provide more power than class-AB_1 operation, but have the disadvantage of placing stiffer requirements on the driver and grid-bias supply regulation.

Calculation of typical operating conditions other than those given in the tube data sheets is slightly more complicated for class-AB_2 and class-B operation than for class AB_1, but is still relatively simple with the procedure outlined below:*

1. Make sure E_b is within tube ratings.
2. Assume a value of I_{bms}. A good starting point is at
   $$I_{bms} = \frac{3\text{ (rated PD)}}{E_b}.$$
   Check this value to see whether it is within ratings. If it is not, use the maximum rated value of I_{bms}.
3. Calculate i'_b: $i'_b = 3I_{bms}$.
4. From the plate characteristics curves, select a value of e_{bmin} near the "knee" of the curves at which i'_b can be obtained. Also record E_{c2}, e_{cm}, i'_{c1} and i'_{c2} for this point.
5. Calculate PD:

* *Calculation for tetrodes is discussed; the triode case is the same except for the omission of the calculation of screen-input power.*

$$PD = \frac{I_{bms}}{4} (E_b + 3e_{bmin}).$$

6. Calculate SI: $SI = \frac{E_{c2} i_{c2}}{4}$

7. Calculate PI: $PI = E_b I_{bms}$.

Check the values found in steps 5, 6, and 7 to determine whether they are within the maximum ratings for the tube type. If the calculated values exceed the maximum ratings, choose a lower value of I_{bms} and repeat steps 3 through 7.

If the plate dissipation and input are below the maximum ratings but the screen input is high, it may be possible to choose a higher value of e_{bmin} in step 4 (and repeat steps 5, 6, and 7) to get all values within ratings. The reverse case can also be applied.

If all the values are well below maximum ratings, a higher value of I_{bms} can be chosen in step 2, and steps 3 through 7 repeated to see whether the operation is still within ratings. If so, this latter set of operating conditions will provide slightly more power output.

When values that are slightly below the maximum ratings are obtained for plate dissipation, screen input, and plate input, the corresponding value of I_{bms} represents the maximum value which can be used at the original plate voltage selected. Lower values of I_{bms}, which give more conservative operation but less power output, can also be used.

Once the value of I_{bms} is selected, the remainder of the calculation follows steps 8 through 13 shown for class AB_1 operation. The driving power (DP) calculated does not include the rf tube and circuit losses. Consequently, for adequate performance, at least ten times this value of power should be available from the driver.

The following example illustrates the calculation of "typical operation" conditions for the class-AB_2, CCS operation of the type 807 with an E_b of 600 volts:

1. The maximum plate voltage rating is 600 v.
2. Determine I_{bms}:

$$I_{bms} = \frac{3\ (\text{rated PD})}{E_b} = \frac{3\ (25)}{600} = .125 \text{ amp.}$$

This value is above the maximum-signal, dc plate-current rating (from tube handbook or tube bulletin); therefore, the maximum rated value of 120 ma will be used as a first approximation.

3. $i'_b = 3I_{bms} = 3\,(120) = 360$ ma.
4. From the 300-v E_{c2} curves, *Fig. 1,* select $e_{bmin} = 90$ v, and read e_{cm} ($= +12$ v). From *Figures 2* and *3,* read $i'_{c1} = 12$ ma, and $i'_{c2} = 35$ ma, respectively.

5. $PD = \frac{I_{bms}}{4} [E_b + 3(e_{bmin})]$

$$= \frac{120}{4} [600 + 3(90)] = 26 \text{ w.}$$

6. $SI = \frac{E_{c2} i_{c2}}{4} = \frac{300(.035)}{4} = 2.6$ w.

7. $PI = E_b I_{bms} = 600\,(.120) = 72$ w.

PD and PI are both above ratings, and a lower value of e_{bmin} at the required current cannot be found on the curves. Therefore, a lower value of I_{bms} must be chosen; try a value of 100 ma, and repeat steps 3 through 7:

3. $i'_b = 3\ (100) = 300$ ma.
4. From the 300-v E_{c2} curves: $e_{bmin} = 70$ v, $e_{cm} = +7$ v, $i'_{c1} = 8$ ma, $i'_{c2} = 35$ ma.

5. $PD = \frac{.100}{4} [600 + 3(70)] = 20.3$ w.

6. $SI = \frac{300(.035)}{4} = 2.6$ w.

7. $PI = 600\ (.100) = 60$ w.

These values are within ratings; therefore, the remainder of the calculations can be completed:

8. $PO = PI - PD = 60 - 20.3 = 39.7$ w.

9. $I_{bo} = \frac{I_{bms}}{5} = \frac{100}{5} = 20$ ma.

10. E_{c1} (from *Fig. 1*) $= -35$ v.

11. $E'_g = [E_{c1}] + e_{cm} = 35 + (+7) = 42$ v.

12. $I_{c2} = \frac{i'_{c2}}{4} = \frac{35}{4} = 8.7$ ma.

13. $DP = \frac{E'_g i'_{c2}}{2} = \frac{42(.008)}{2} = .17$ w.

These values compare reasonably well with the published values.

(*Continued on Page 5*)

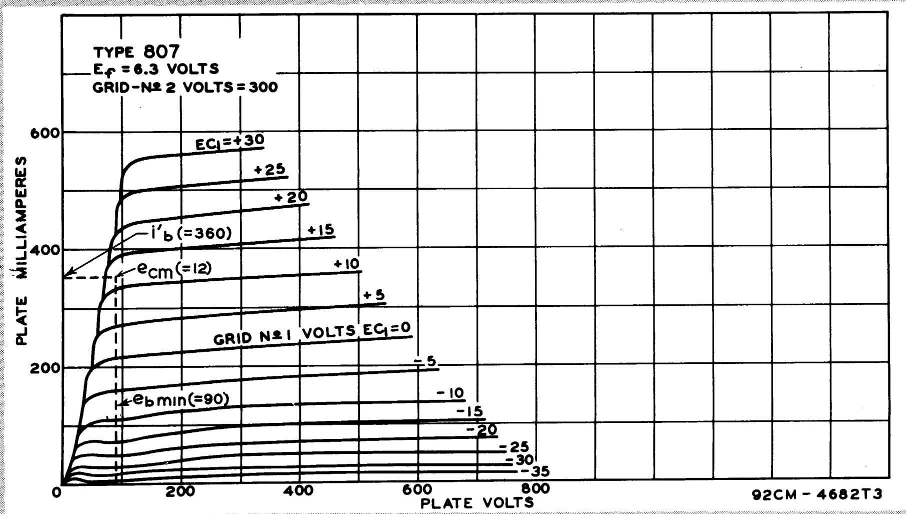

Fig. 1. Average plate characteristics for the type 807 tube (grid-No. 2 voltage = 300).

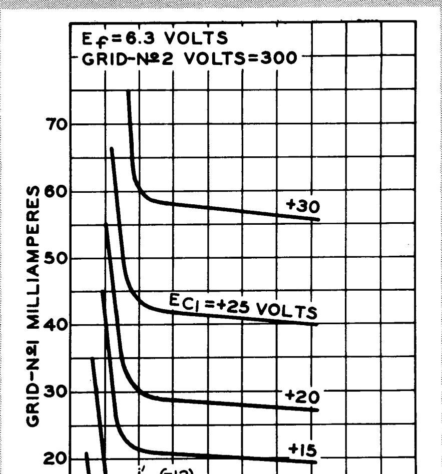

Fig. 2. Average control-grid characteristics for the type 807 tube grid-No. 2 voltage = 300).

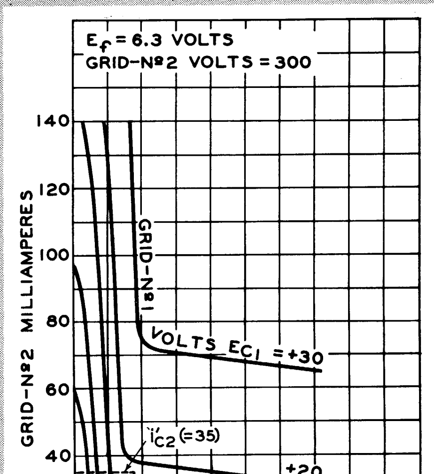

Fig. 3. Average screen-grid characteristics for the type 807 tube grid-No. 2 voltage = 300).

(*Continued from Page 3*)

Table I shows the maximum ratings and typical operating conditions for several popular RCA tubes in linear rf amplifier service for single-sideband, suppressed-carrier transmission.

It should be remembered that the typical operating conditions shown by the manufacturer (or calculated by the preceding methods) are approximate only. Minor adjustments are usually made in actual operation by varying the grid bias or screen voltage slightly. In linear rf amplifier circuits for single-sideband, suppressed-carrier transmission, it is particularly important to check the actual operating conditions when the transmitter is first set up to assure that linear operation within the maximum tube ratings is being obtained.

Table I—Ratings and Operating Conditions for RCA Tubes Used as Linear RF Power Amplifiers

			Maximum Ratings - Absolute Values							Typical Operation								
Tube Type	Class of Operation	Service	Plate Voltage (E_b)	Screen Voltage (E_{c2})	Max-Signal Plate Current (I_{bms})-ma	Max-Signal Plate Input (PI)-watts	Max-Signal Screen Input (SI)-watts	Plate Dissipation (PD)-watts	Grid Resistance -ohms	Plate Voltage (E_b)	Screen Voltage (E_{c2})	Grid Voltage (E_{c1})	Peak Grid Voltage (E'_g)	Zero-Signal Plate Current (I_{bo})-ma	Max-Signal Plate Current (I_{bms})-ma	Max-Signal Screen Current (I_{c2})-ma	Drive Power (DP) -watts	Max-Signal Power Output (PO)-watts
2E26	AB_1	CCS	400	200	75	30	2.5	10	30 K	400	200	-25	25	9	45	10		12
		ICAS	500	200	75	37.5	2.5	12.5	30 K	500	200	-25	25	9	45	10		15
	AB_2	CCS	400	200	75	30	2.5	10		400	125	-15	30	10	75	16	0.2	20
		ICAS	500	200	75	37.5	2.5	12.5		500	125	-15	30	11	75	16	0.2	25
4-65A	AB_1	CCS	3000	600	150		10	65	250 K	1000	500	-85	85	15	85	12		40
										1500	500	-85	85	15	90	7		70
										1750	500	-90	90	10	85	9		85
	AB_2	CCS	3000	600	150		10	65		1000	250	-30	105	30	150	22	2.5	85
										1500	250	-35	100	30	125	15	1.5	125
										1800	250	-35	90	25	110	13	1.0	135
4-125A	AB_1	CCS	3000	600	225		20	125	250 K	1500	600	-90	90	30	110	9		80
										2000	600	-94	94	25	120	3		115
										2500	600	-96	96	25	115	4		165
	AB_2	CCS	3000	400	225		20	125		1500	350	-41	141	44	200	17	5.0	175
										2000	350	-45	105	36	150	3	3.0	175
										2500	350	-43	139	47	130	3	2.5	200
4-250A	AB_1	CCS	4000	600	350		35	250		2000	500	-88	88	55	200	11		230
										2500	500	-90	90	60	215	7		310
										3000	500	-93	93	60	205	5		370
	AB_2	CCS	4000	600	350		35	250		2000	300	-48	100	60	255	13	5.5	325
										2500	300	-51	100	60	250	12	5.0	420
										3000	300	-53	100	62	236	16	4.5	520
807 1625	AB_1	CCS	600	300	120	60	3.5	25	100 K	500	300	-32	32	22	70	8		23
										600	300	-34	34	18	70	8		28
		ICAS	750	300	120	90	3.5	30	100 K	750	300	-35	35	15	70	8		35
	AB_2	CCS	600	300	120	60	3.5	25		500	300	-30	43	30	120	10	0.2	38
										600	300	-32	40	24	100	9	0.1	40
		ICAS	750	300	120	90	3.5	30		750	300	-35	48	15	120	10	0.2	60
811A	B	CCS	1250		175	165		45		750		0	100	16	175		10	90
										1250		0	78	25	130		4	120
		ICAS	1500		175	235		65		1000		0	93	22	175		7.5	125
										1250		0	88	27	175		6	155
813	AB_1	CCS	2250	1100	180	360	22	100		2000	750	-90	80	25	130	20		165
										2250	750	-95	85	25	125	26		190
		ICAS	2500	1100	225	450	22	125		2500	750	-95	90	25	145	27		245
829B Natural Cooling	AB_1	CCS	750	225	250	100	7	30	100 K	500	200	-20	40	20	100	20		35
										600	200	-18	36	40	100	18		44
		ICAS	750	225	250	120	7	40	100 K	750	200	-21	42	20	100	20		55
	AB_2	CCS	750	225	250	100	7	30		500	200	-18	50	30	180	26	0.6	60
										600	200	-20	50	26	155	22	0.4	65
		ICAS	750	225	250	120	7	40		750	200	-19	50	32	160	25	0.5	85
832A	AB_1	CCS	750	250	90	36	5	15	100 K	500	180	-30	60	14	70	7		22
										600	150	-30	60	12	60	7		23
		ICAS	750	250	115	50	5	20	100 K	750	150	-32	64	12	60	7		30
833A	B	ICAS	3300		500	1300		350		3300		-80	190	60	300		20	710
6146 6159	AB_1	CCS	600	250	125	60	3	20	100 K	400	190	-40	40	32	114	13		27
										500	185	-40	40	29	108	13		35
										600	180	-45	45	13	100	12		40
		ICAS	750	250	135	85	3	25	100 K	600	200	-50	50	14	115	14		47
										750	195	-50	50	12	110	13		60
	AB_2	CCS	600	250	125	60	3	20		400	175	-41	48	17	116	9	0.2	31
										500	175	-44	51	14	121	9	0.3	41
										600	165	-44	49	11	104	9	0.2	45
		ICAS	750	250	135	85	3	25		600	190	-48	55	14	135	10	0.3	55
										750	165	-46	54	11	120	10	0.4	65
6524	AB_2	CCS	500	300	150	70	3	20	30 K	400	200	-23	72	25	145	10	0.1	39
										500	200	-26	70	20	116	10	0.1	40
		ICAS	600	300	150	85	3	20	30 K	500	200	-25	76	25	145	10	0.1	50
										600	200	-26	76	21	135	13	0.1	57

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144-Megacycle Transmitter

72-Watts Input on 144 Mc with an RCA-5894

By R. M. Mendelson,* W2OKO

The appearance of a new tube often prompts the adventurous ham to re-appraise his equipment with a critical eye. W2OKO looked over the specifications for the new RCA-5894, a high-efficiency version of the 829, and found it was time he built an up-to-date 144-Mc rig. The result is a transmitter that takes advantage of the best features of this high-frequency twin beam power tube. Ready for 72 watts of modulated input, the circuit described below incorporates stable VFO tuning, broad-band multipliers for a minimum of tuning controls, a high-efficiency tank circuit, and coaxial output with antenna switching.

Since attention to wiring and construction detail often spells the difference between R3 and R5 at 144 Mc, more than usual "how-to" information will be supplied for this rig. The transmitter will be described in two parts. Part I contains a description of the set, the circuit diagram and parts list, and advice on wiring and construction for those who want to get off to an early start. Adjustment and operation will be described in Part II.

The RCA-5894, a twin beam power tube designed to operate at frequencies up to 400 or 500 Mc, offers many advantages in a modern 144-Mc rig. Since a survey of recent literature disclosed little information on how to capitalize on the tube's possibilities, the transmitter described in this article was developed.

The VFO and multiplier tubes are all well-known ham types. A 5894 is used for the final stage; this tube has balanced structure with low interelectrode capacitances and low cathode inductance. The 5894 is internally neutralized, eliminating all need for external neutralizing circuits. These features, plus the 5894's low rf losses and high power sensitivity, make it an excellent choice for operation with a full 'phone input of 72 watts at 144 Mc.

The complete schematic diagram is shown in Figure 3. The VFO operates in the 8-Mc range, using a 6AU6 in a conventional Clapp oscillator and feeding into a 5763 buffer stage. A 5763 multiplier stage triples to 24 Mc. By means of switch S_1, this stage may also be used as a crystal oscillator for scheduled contacts, net operations, etc. A second 5763 multiplier doubles to 48 Mc to feed a pair of 5763's in a push-pull tripler that drives the final.

The buffer and the two single-tube multi-

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pliers use slug-tuned coils in self-resonant plate circuits. When the coils are peaked for 146-Mc operation, they give adequate drive from 144 to 148 Mc. The push-pull tripler, capacitively coupled to the final, also provides ample, well-balanced drive over the entire band. Screen-voltage divider R_{17} controls the amount of drive, while R_{18} prevents accidental lowering of drive below a safe value.

To prevent a parasitic oscillation in the final, it was necessary to use a series-tuned screen bypass circuit formed by C_{29} and the internal tube screen-lead inductance. R_{21} serves a dual purpose. First, it acts as a screen-voltage dropping resistor. Since it is wire-wound, however, it also serves as an rf choke at 144 Mc. Its location is important and is discussed under "Construction."

The efficiency of the final circuit stems from the 5894 and from its tank design. This type of design was described in *Electronics,* May, 1947 (p. 130), and sample calculations were given for 144 Mc. Referring to Figure 6, note that the basic circuit is a pair of parallel lines surrounded by a large copper shield. The parallel lines terminate in a copper disk. Separated from this disk by a mica insulator is another copper disk which forms the "bottom" of the shield. The shield prevents radiation from the tank lines and raises the circuit Q considerably.

Loading is varied, and output is taken by means of a movable hairpin loop coupled to the shorted end of the tank. As can be seen from Figure 3, the shield disk and mica insulation also act as an rf bypass capacitor (C_{32}) for this end of the tank line. Dimensions of the components are fairly critical. The parts can be machined easily, however. They can also be made with hand tools if proper care is exercised. Details are included under "Construction."

Because of the push-pull operation, it is essential that the plate circuits of the 5894 be balanced if both plates are to run cool. Since a balanced antenna coupling is indicated, the hairpin loop should not be used to couple directly to a coaxial line. To make the coupling, a conventional antenna tuner cut for 144 Mc (*QST*, January, 1952, p. 50) is used in reverse. For feeding 50-ohm coaxial line, the input taps on the coil will be approximately one-half turn in from each end; however, they are best located experimentally—as described under "Operation."

Transmitter Layout

As shown in the panel layout, tuning controls are necessary only for the last multiplier plate and the final plate, and are located just below the grid-current and plate-current meters. From left to right across the bottom row are the final excitation control, the crystal-VFO selector, crystal sockets, the filament switch, and antenna loading and tuning controls. Filament and high-voltage pilots and a fuse holder complete the lower level. The VFO tuning knob, calibration dial, and band-set adjuster are in the upper right corner of the panel.

The rig is built on a 17″ x 13″ x 3″ steel chassis bolted to a 19″ x 8 ¾″ steel panel. Because of the frequency multiplication of 18 times from VFO to final, it is best for good stability to use steel here and provide strong panel-to-chassis bolting.

Figure 1. Panel view of the 144-Mc transmitter. VFO bandset control is directly above the center of the VFO dial.

The VFO and buffer stages are mounted on the left side of a steel box behind the right end of the panel. The first two multiplier stages are on the left of the chassis toward the front. The tripler-driver is located back of the doubler, on a sub-chassis and in line with the socket of the final tube. This arrangement allows short coupling leads to the final. Its symmetry also helps to keep the final grid circuit balanced. The 5894 is mounted horizontally, allowing easy connection to the plate tank circuit and adequate ventilation around the tube. This method also keeps heat from getting to the tuned lines where it might affect tuning stability. Tripler and final tuning controls are brought to panel mounts by simple pulley arrangements, as shown in Figure 5.

Antenna link coupling is made at the cold end of the tank lines and is carried by two feed-through bushings below the chassis to the antenna tuner.

The voltage-regulator tube for VFO plate and screen voltage is at the back of the chassis. On the chassis back wall are the antenna and receiver coax connectors and the power input plug.

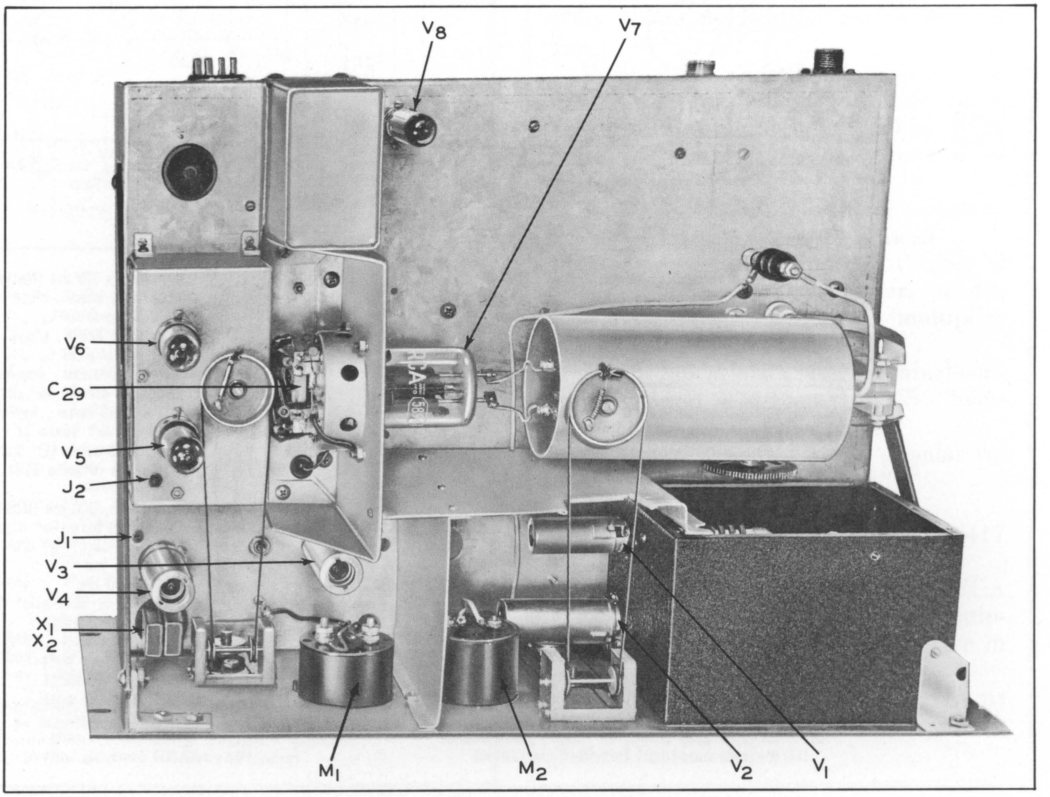
Construction

If the usual precautions against feedback are observed, no difficulties should be encountered in the construction of this transmitter. Keep all rf leads as short as possible. Only dc and filament leads may be cabled; even on these, adequate rf bypassing should be used close to the tube sockets.

The VFO box is held to the panel with 12 screws. It has no rigid connection to the chassis. Added strength is provided by the use of 12 more screws to fasten the back plate to the box. Heat from the tubes is dissipated outside the box, because only the cold components and the rf tuned circuit are placed inside. Note that a bus-bar is used for all VFO and buffer ground connections. The bus-bar is grounded to the chassis only at the tuning capacitor rotor (C_2). Design of this sort has proved valuable in obtaining a steady VFO frequency. (See VFO described in HAM TIPS, December, 1953.)

The VFO coil is made of 2″ B & W coil stock, chosen for strength and high Q. The

Figure 2. Top view. Note expansion loops in plate leads of the RCA-5894. The two pulley assemblies can also be seen.



coil is best mounted by gluing to a piece of Lucite, using any good plastic cement between the Lucite and the coil's plastic frame. This larger Lucite piece may then be bolted to the front panel on 1″ porcelain standoffs. Keep the coil as far as possible from the cabinet walls. The tuning capacitor, which should be of the two-bearing type, is also bolted to the front panel. In this way the lead from coil to condenser is kept short; more important, the capacitor and coil are kept rigid with respect to each other.

To insure good shielding, paint should be scraped from the back of the panel where the VFO box makes contact. Similarly, scrape the paint from the area of contact between the box and its back cover.

Wiring of the multipliers up to the push-pull tripler requires no comment except to repeat the advisability of shoft rf leads.

Link coupling is used to the grids of the tripler because of its location. Feed-through bushings fix link coil L_6 and allow the tripler sub-chassis to be lowered into place after both the sub-chassis and socket wiring for the final have been completed.

Filament, plate, and screen leads from the sub-chassis are fed through a grommet and wired later to their proper points under the chassis. The grid coil is broad-tuned and is adjusted when the transmitter is put into operation. For reduced lead inductance, it is advisable to use 5⁄16″-wide copper ribbon for the plate-to-tank leads. The use of tube shields on this stage is not recommended since the loss of rf power through the added plate-ground capacitance will be excessive.

In wiring the final socket (which should contain ventilating holes and be shielded and sunken), note that the screen lead and grid return are fed through the chassis by bushings. Copper ribbon is used from the screen to its feed-through. The screen bypass trimmer should be mounted across the socket to the point at which the heater and cathode are grounded. Place it at a slight tilt so that it may be tuned from above. Under the chassis, the screen dropping resistor is mounted directly on the feed-through bushing and is bypassed by a high-voltage mica capacitor (C_{30}) at the B + end. The grid-

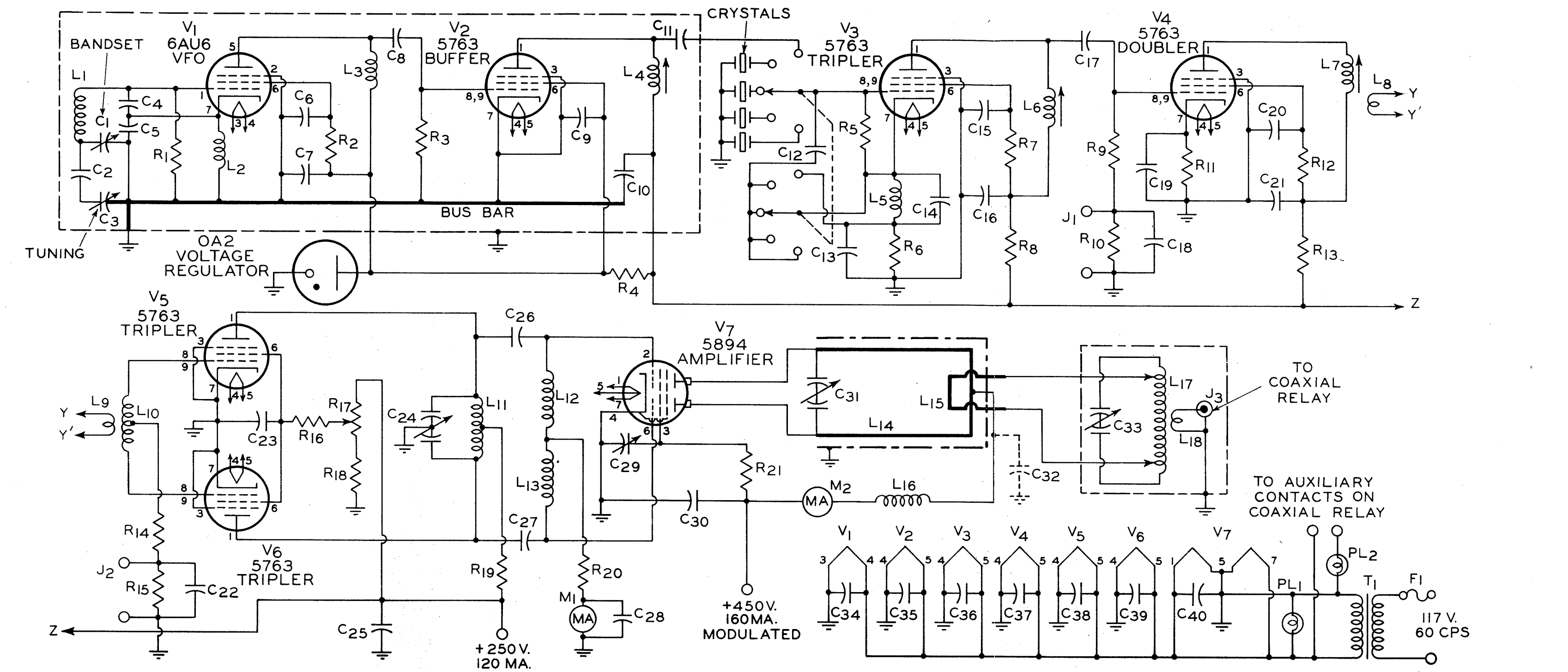


Figure 3. Schematic diagram and parts list.

C_1	50 μμf variable (Hammarlund APC-50)
C_2	5 μμf ceramic, zero temp. coeff. (Erie NPOK-050)
C_3	15 μμf variable, dual bearing (National SEU-15)
$C_{4,5}$	500 μμf silver mica (El-Menco CM15-E501J)
$C_{6,7,9,10,13,15,}$ $C_{16,34,35,36,40}$	0.01 μf ceramic (Centralab CRL D6-103)
$C_{8,17}$	50 μμf ceramic (Erie GP1K-500)
C_{11}	100 μμf ceramic (Erie GP1K-101)
C_{12}	10 μμf ceramic (Erie GP1K-100)
C_{14}	150 μμf ceramic (Centralab CRL D6-151)
$C_{18,19,20,21,22,23}$ $C_{28,37,38,39,41}$	0.001 μf ceramic (Centralab CRL D6-102)
$C_{24,31}$	10 μμf per section butterfly (Hammarlund BFC-12)
C_{25}	2 μf oil, 600 WVDC (Cornell Dubilier TJU 6020)
$C_{26,27}$	20 μμf ceramic (Erie GP1K-200)
C_{29}	7-45 μμf variable ceramic disk (Erie TS2A-7)
C_{30}	0.002 μf mica, 2500 WVDC (Cornell Dubilier Type 9L)
C_{32}	See text
C_{33}	15 μμf per section variable (Hammarlund HFD 15X)
F_1	Fuse, 3AG, 1 amp.
$J_{1,2}$	Insulated phone tip jacks
J_3	Output jack to coaxial relay
L_1	20 turns #16, 2″ diam., 2″ long (B&W 3907 coil stock)
$L_{2,3}$	RFC, 2.5 mh, 125 ma (National R-100U)
L_4	23 turns #26 enam., ½″ diam., close-wound (on slug-tuned coil form National XR-50)
L_5	RFC, 2.5 mh, 125 ma (National R-100)
L_6	7 turns #26 enam., close-wound on same type form as L_4
L_7	4 turns #26 enam., close-wound on same type form as L_4
L_8	2 turns #16 enam., coupled to L_7
L_9	1 turn #16 enam., ¾″ diam.
L_{10}	20 turns #16 enam., ½″ diam., spaced wire diam., plus ¼″ space at center for L_9
L_{11}	2 turns #16 bare, ½″ diam., spaced ⅛″
$L_{12,13}$	RFC, 1.8 μh (Ohmite Z144)
$L_{14,15}$	See text
L_{16}	RFC, 2.5 mh, 300 ma (National R-300ST)
L_{17}	5 turns #16 bare, ⅝″ diam., spaced ⅛″
L_{18}	1 turn #16 bare, ¾″ diam.
M_1	Meter, 0-15 ma
M_2	Meter, 0-500 ma
$PL_{1,2}$	6-8 v, #40 or #47 pilot lights
R_1	47,000 ohms, 1 watt
$R_{2,8,13}$	1,000 ohms, 1 watt
R_3	50,000 ohms, ½ watt
R_4	3,000 ohms, 10 watts
R_5	68,000 ohms, ½ watt
$R_{6,11}$	330 ohms, ½ watt
$R_{7,12}$	12,000 ohms, 1 watt
R_9	82,000 ohms, ½ watt
$R_{10,15}$	1,000 ohms, ½ watt
R_{14}	33,000 ohms, ½ watt
R_{16}	8,000 ohms, 1 watt
R_{17}	20,000 ohms, wire-wound variable, 2 watts
R_{18}	20,000 ohms, 2 watts
R_{19}	100 ohms, 1 watt
R_{20}	10,000 ohms, 1 watt
R_{21}	15,000 ohms, wire-wound, 20 watts
S_1	DP 5-position ceramic rotary switch (Centralab 2505)
T_1	6.3 v, 10 amp (Stancor P6308)
	Miscellaneous
Chassis	17″ x 13″ x 3″ steel (ParMetal B-4536 or C-4536)
Panel	19″ x 8¾″ x ⅛″ steel (ParMetal 6604 or G6604)
Sub-chassis	5″ x 3″ x 2″ (Open-side half of Flexi-mount ICA-29341, or bend from aluminum stock)
VFO shield box	6″ x 5″ x 4″ steel (ICA-3812)
Ant. tuner box	4″ x 4″ x 2″ aluminum (ICA-29810)
Coaxial relay	(Advance CB/1C2C/115VA)

Note: Manufacturer's names and part numbers are given only to identify components used in this transmitter. Equivalent components by other manufacturers may be substituted wherever desired.

bias resistor is mounted between its feed-through and a stand-off, from which a lead runs to the grid meter. Again, 5/16″ flexible copper ribbon, having a U-bend to take up thermal expansion, is used for plate-to-tank leads. This construction prevents the plate-terminal seals from being subjected to any strain.

The shields shown in the top views of the chassis keep any final rf away from earlier stages. They also separate the final grid and plate meters. These shields were installed during the design trouble-shooting of the rig but may not be necessary.

Depending on available facilities, some ingenuity may be required to build the final tank. The disks may be cut easily if a drill press and fly cutter are used; if not, a hack saw and file will do an acceptable job. The copper shield tubing may be obtained from any large plumbing-supply house. If the dimensions shown are used, the tank will be right on frequency.

In this tank, a spacer of laminated mica and fiber glass was used. Regular mica may be substituted, however. The thickness should be at least 1/16″ to prevent arc-over but is not critical otherwise. Teflon sheet of at least the same thickness also may be used. Teflon was used here to hold the antenna coupling loop in alignment. Lucite may also prove satisfactory. In any event, these fittings should be kept snug to hold their setting.

In the transmitter shown, a mechanical linkage is used to vary the antenna loading. This linkage was put in before final design was reached and proved to be an unnecessary refinement. Once set, the link will

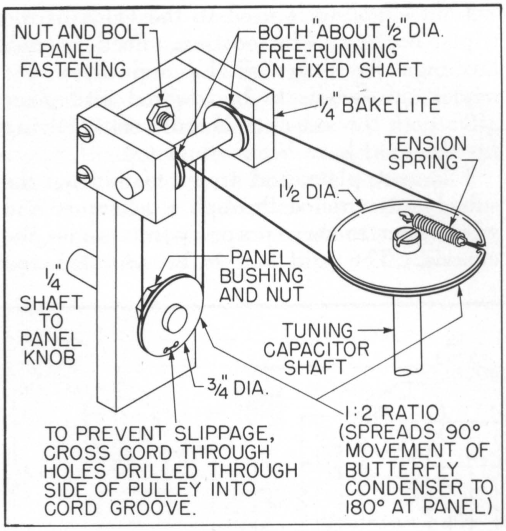
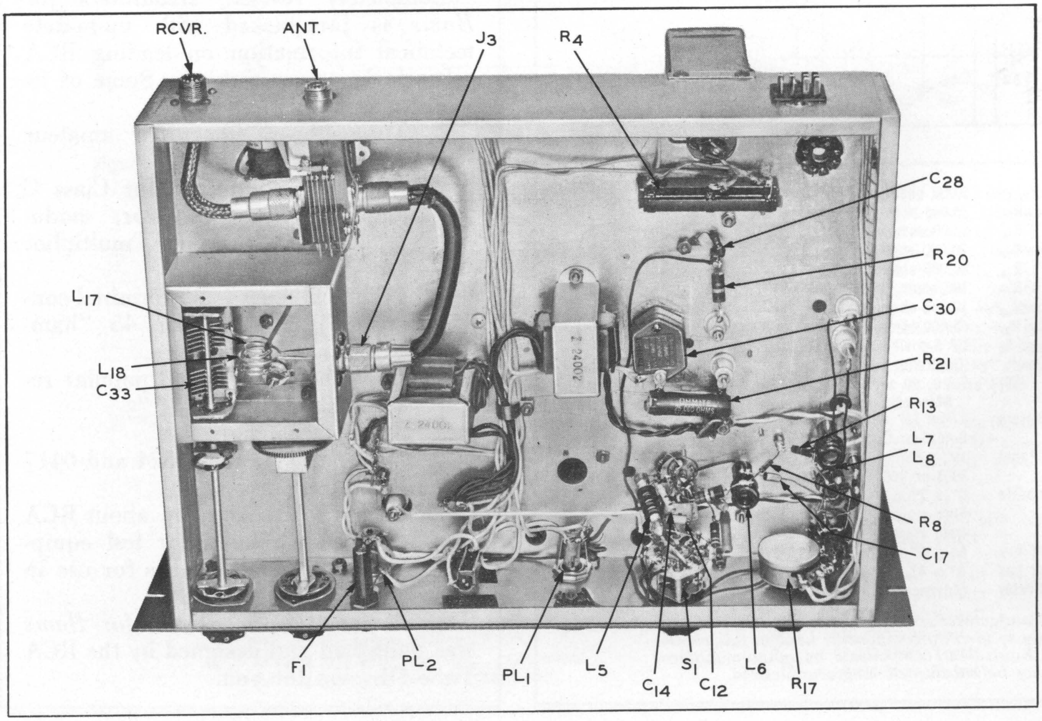


Figure 5. Suggested construction for the two pulley drives.

Figure 4. Bottom view, showing arrangement of components for shortest rf leads.



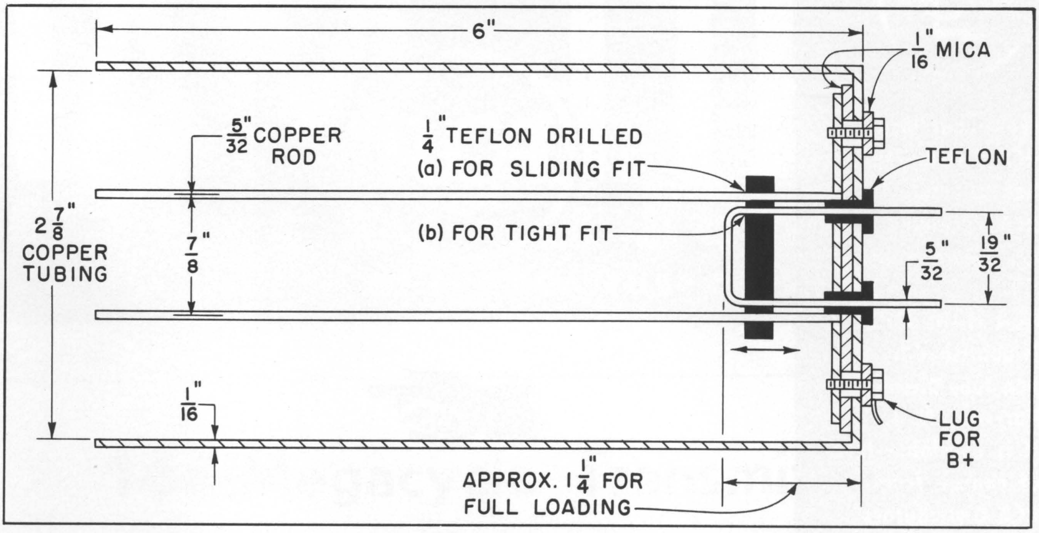


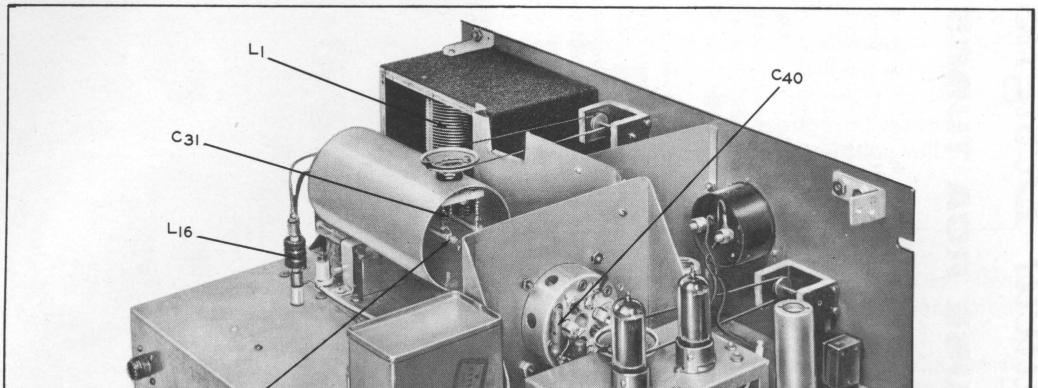
Figure 6. Construction details for the 144-Mc final tank assembly.

not have to be moved very often—even with relatively large frequency changes.

Be sure the plate tuning capacitor (mounted just inside the shield tubing) is insulated from ground, but that the shield itself is well grounded for rf by a 1″ copper ribbon at the plate end. These precautions, together with the system of screen bypassing used, will prevent a 200-Mc parasitic oscillation that may otherwise appear.

The antenna tuner is straightforward except that its capacitor rotor is also insulated from ground. Use ½″ stand-offs and an insulated shaft coupling. Keep this circuit well shielded. Because the rf fields at the tuner are strong, complete enclosure is essential to prevent possible TVI and feedback to earlier stages.

Figure 7. Detail view showing arrangement of components on the sub-chassis and the final socket.



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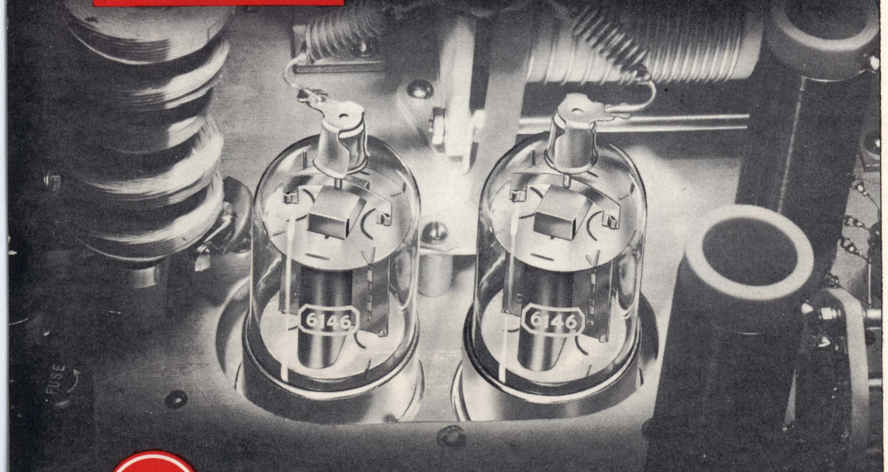

Close-up view of the RCA-6146's in parallel— in the final amplifier of the Johnson Viking II.

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HAM TIPS

A PUBLICATION OF THE RCA TUBE DIVISION

Vol. XV, No. 2 August, 1955

144-Megacycle Transmitter

Part II: Operation and Adjustment

By R. M. Mendelson,* W2OKO

A description of this circuit and the schematic diagram and parts list appeared in Part I in the May issue of HAM TIPS. If you missed Part I, ask your RCA distributor for a copy.

Operation

After all wiring has been checked, insert RCA's 5763 crystal oscillator-tripler (V_3) and 5763 doubler (V_4). Use an 8-Mc crystal that will put the final signal near 146 Mc. If the coils are peaked for this frequency there will be adequate drive at both ends of the band. (A grid-dip meter to tune the coils roughly is a help. It is not essential, however.) Plug a 1- or 2-ma meter into J_1, apply 250 volts to the oscillator circuit and tune the plate of the oscillator (L_6) for a maximum reading. Approximately ½ to 1 ma should be obtained easily.

Now insert the push-pull tripler 5763's (V_5 and V_6) but do not connect them to B+. Move the meter to J_2 and add the doubler (V_4) to the B+ line. Tune doubler coil L_7 for maximum reading—between .75 and 2 ma. Spread or squeeze the tripler grid coils (L_{10}) for the highest maximum reading. If this reading is

*RCA Tube Division, Harrison, N. J.

still too low, it may be necessary to couple link L_8 closer to the doubler coil. Moving this link will necessitate a touch-up of the doubler slug.

Insert the RCA-5894 final without B+ and let it warm up for 2 minutes. While waiting, set the screen bypass trimmer to the middle of its range. B+ should then be applied to all the multipliers but not to the final. Set excitation control R_{17} to maximum. Tune for maximum final grid-current by adjusting the plate-tank capacitor of the push-pull tripler. At least 5 ma should be indicated. Values of 8 ma have been obtained easily on the transmitter built. Back down R_{17} to give a reading of 4 to 5 ma.

Before applying high voltage to the final, it is wise to check for parasitics. Remove excitation by pulling out tripler tubes V_5 and V_6. Apply about 100 volts to the 5894 plate and screen circuit. Tune the final and push-pull tripler tuning capacitors through their ranges. If any combination of settings shows grid current, it indicates parasitic oscillation in the final stage. The usual procedure for hunting parasitics at VHF apply, but first make certain that the rotor of the final tuning capacitor is ungrounded. Adjustment of the screen bypass trimmer also may help. This trimmer setting is not critical, but in the absence of parasitics it should be set for maximum final grid current.

itance. Apply high voltage to the final, then immediately tune tank capacitor C_{31} for a dip in plate current. Adjust the antenna tuner for a maximum plate-current reading. The load bulb should light brightly.

With 450 volts on the plate, the current should be kept below 160 ma. If plate current is much less than this value, the loading may be increased by moving the antenna link a bit further in on the tank lines *(First, turn off the power.)* Little movement is necessary to obtain full load.

To check the antenna-coil tap spacing, replace the dummy load with the antenna coaxial feed-line and repeat the tuning procedure—starting with minimum coupling to the final tank. Begin with the antenna coil taps about ½ turn from each end. If peaking the antenna tuner changes plate tuning, move the taps about ⅛ turn. Repeat the tuning procedure until the correct tap points are found. You are now "on the air," crystal controlled.

VFO Adjustment

To start the VFO, remove power from final and multiplier stages and insert RCA's 6AU6 oscillator and 5763 buffer (V_2). Set the panel selector switch to "VFO" and apply B+ to the 6AU6. It should now be oscillating and its range may be checked on any communications receiver. For complete two-meter-band cover-

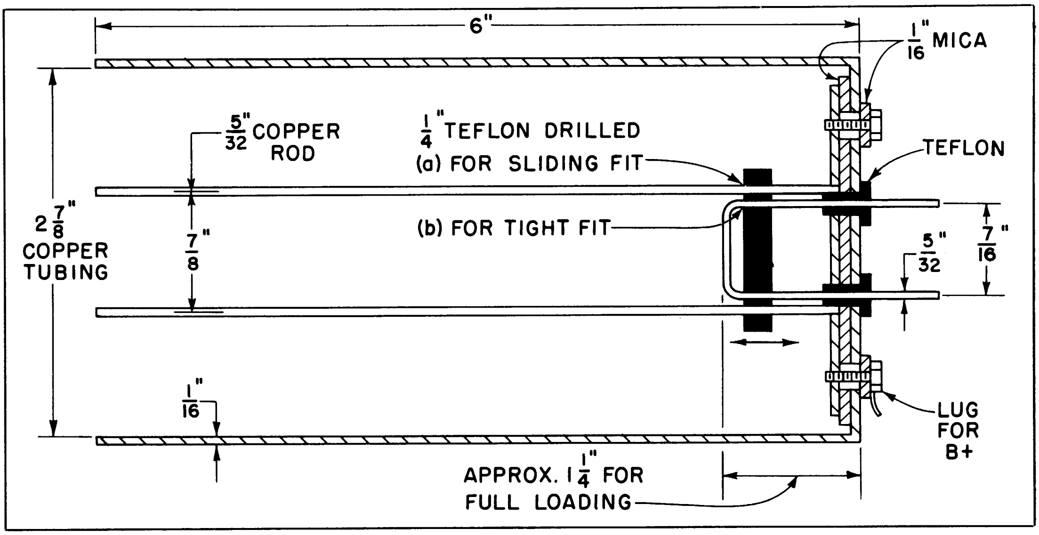

Figure 1. Transmitter tank assembly. Note corrected figure of 7/16" center-to-center for the antenna link.

The tripler tubes may now be reinserted and their plate circuit retuned for maximum final grid current. Next, a 100-watt lamp dummy load should be attached to the antenna tuner output. Pull the coupling link full out and set the antenna tuner for maximum capac-

age, the oscillator should tune from 8.00 to 8.22 Mc. Use C_1 to set the band edge. Calibration may be done either with the fundamental, on the low-frequency receiver or, later, on a two-meter receiver.

With the oscillator running, it is now only

necessary to tune the buffer plate to 8 Mc. Set the VFO to mid-band (8.11 Mc) and apply high voltage to all stages except the final. (The final may not have sufficient excitation until the buffer is adjusted.) Tune the buffer coil for maximum grid current at the final. The 5894 may now be fired up.

There will be a slight drop in final grid current when the VFO is tuned away from the center of the band, but adequate drive (4-5 ma) can always be obtained by proper setting of excitation control R_{17}.

Some thought was given to protecting the 5894 against loss of excitation. The use of a clamp tube on a modulated final is difficult at 144 Mc, where wires easily become quarter-wave lines. In the end, no protective devices were added here. No trouble has been encountered—so far.

Acknowledgment

The author wishes to thank James A. Shiels, K2DI, and Frank Maraguglio, W2LXB, for their ideas and aid in constructing the final tank and antenna tuner.

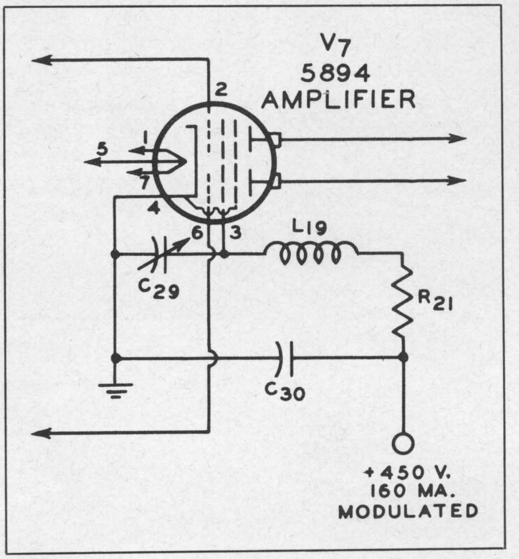

Figure 2. Original circuit used R_{21} without additional 5894 screen-lead choke, but addition of L_{19} (Ohmite Z-50) allows more complete neutralization of the final.

Addenda

In Part I, the center-to-center measurement for the antenna link (L_{15}) was incorrectly noted as 19/32″. The correct dimension is 7/16″.

Also in Part I it was noted that R_{21} served both as resistor and rf choke. It has been found, however, that the addition of an actual rf choke allows more complete neutralization of the final. (See Figures 2 and 3.)

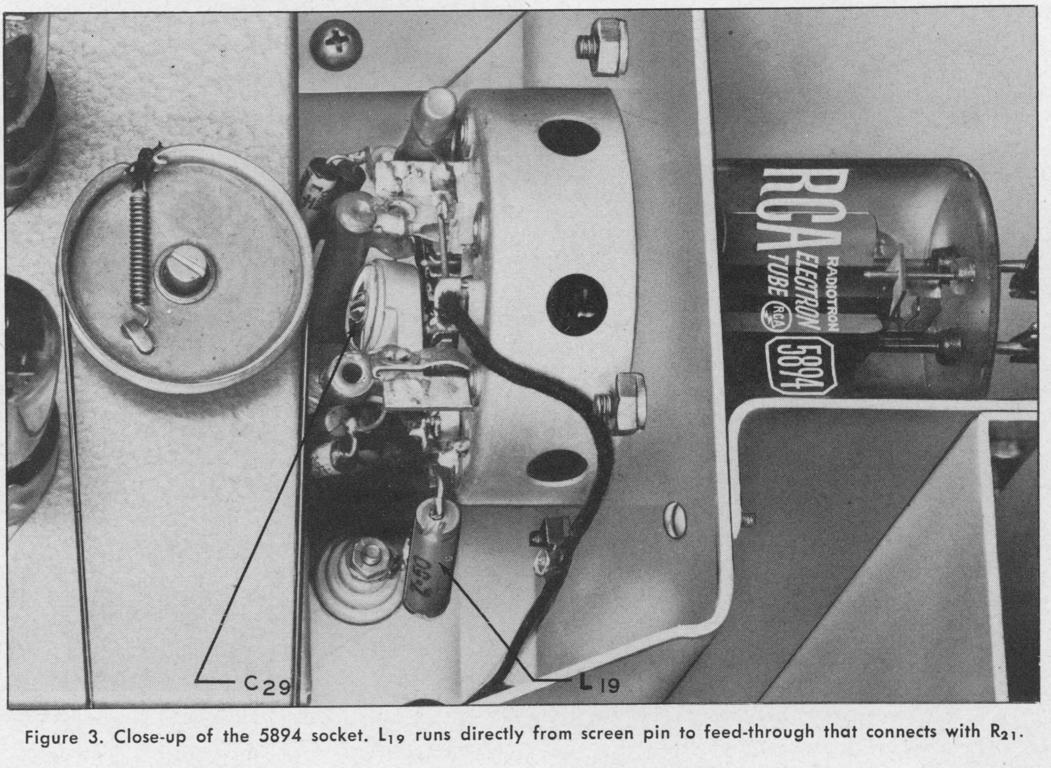

Figure 3. Close-up of the 5894 socket. L_{19} runs directly from screen pin to feed-through that connects with R_{21}.

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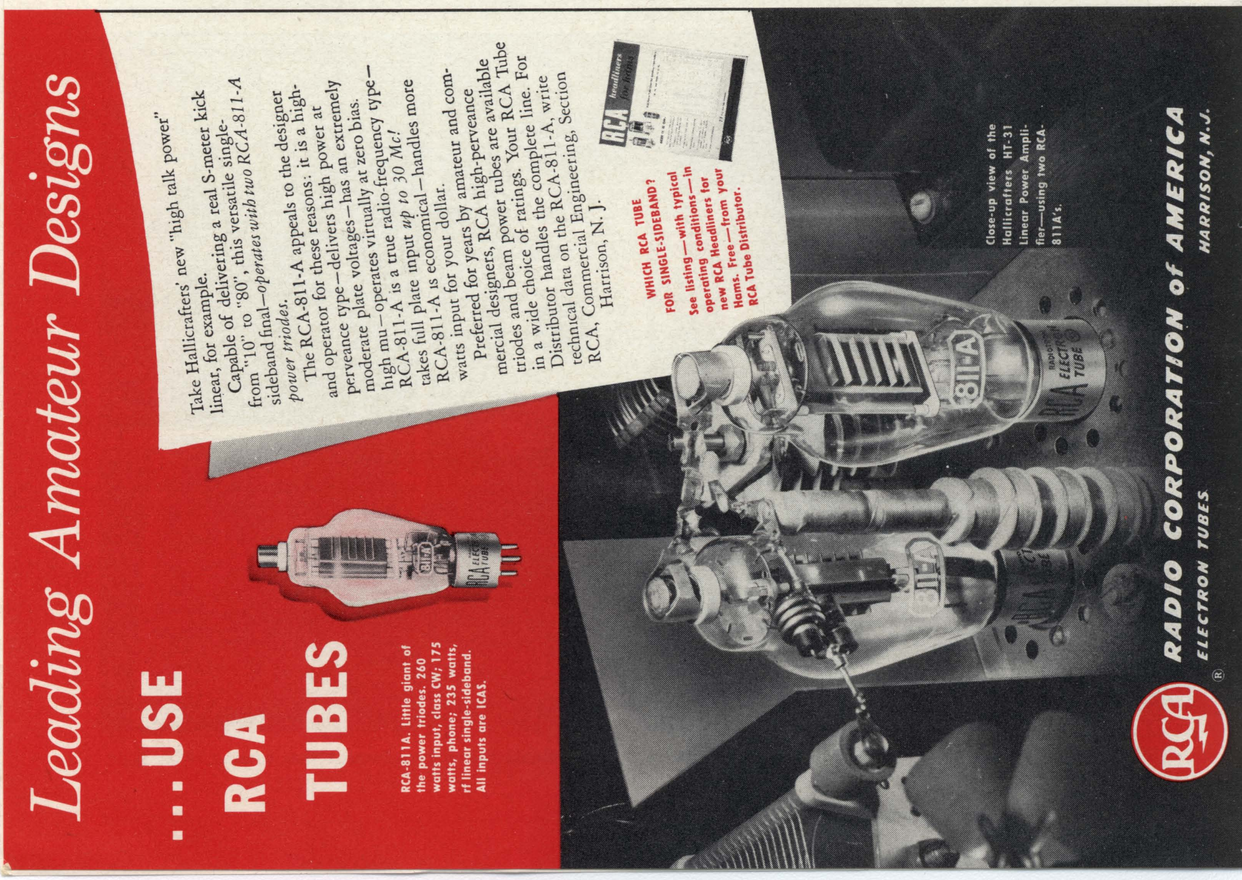


HAM TIPS

A PUBLICATION OF THE RCA TUBE DIVISION

Vol. XV, No. 3 October, 1955

Single-Ended Class-C Amplifier Design

By Clarence A. West, W2IYG

RCA Tube Division, Harrison, N. J.

The July-August, 1954 HAM TIPS gave a simplified procedure for the design of pi-coupled amplifiers. Now, W2IYG steps forward to discuss simplified design for single-ended Class-C amplifiers using balanced plate tank circuits.

Although much of the material presented here has been published piecemeal in one form or another, W2IYG has gathered the important considerations into this one article and boiled them down into simple, practical form.

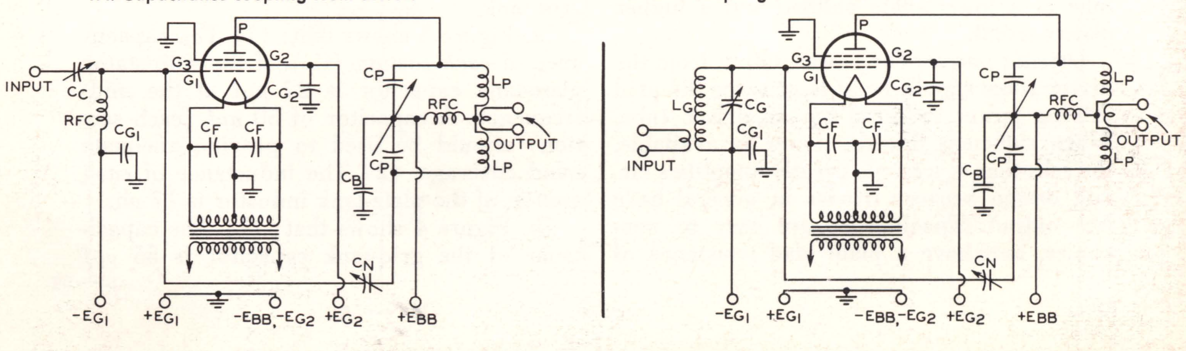
The basic circuit for single-ended Class-C amplifiers is essentially the same regardless of the tube type used; the chief problem confronting the designer is the selection of the proper component values for this circuit. The tuned circuits present the greatest difficulty, especially for those who plan to make their own coils and select capacitors suitable for use with these coils. The selection of other circuit components may also pose problems.

This article presents a "rule-of-thumb" approach to the selection of components for use in the circuits shown in Figures 1A and 1B. This approach, which eliminates the use of formulas and equations, provides workable circuits having adequate efficiency for most "ham" uses. A nomograph and a series of charts and curves enable the designer to determine quickly the value and rating of all circuit components including the physical constants of the coils. The step-by-step design procedure is as follows:

1. Select a suitable tube type.
2. Select a circuit, Figure 1A or 1B.
3. Select tube power output from tube data.
4. Determine peak plate voltage by multiplying dc plate voltage by 0.85.
5. On Nomograph, Figure 2, place straightedge on these values of power output and peak plate voltage. Read "Plate Load" value.
6. Place straightedge from this plate load value to the "Amateur Band" desired. Read

Figure 1. Basic Circuits. (When triodes are used, omit Grid-No. 2 and Grid-No. 3 circuitry.)

1A. Capacitance coupling from driver. 1B. Link coupling from driver.



"Reactance X_C and X_L" value.

7. In Figures 3 and 4, *Reactance vs Capacitance and Inductance Curves,* read the values of tank capacitance and tank inductance required.

8. Determine minimum capacitor spacing, from Figure 8.

9. From Figure 5, *Coil Curves,* determine diameter, length, number of turns, and wire size required.

10. From Figure 6, *Miscellaneous Circuit Components Chart,* select values of other circuit components.

Before we run through a typical example, it is worth while to consider the important factors which influence tube selection.

Tube Selection

The selection of a tube to be used in the circuits covered by this article should not be made on the basis of tube power output alone. Equally important factors are: (1) tube output capacitance; (2) plate load; (3) driving power.

Tube output capacitance. This capacitance is added to the tank-circuit capacitance—thus changing the tank circuit's resonant frequency. At the lower frequencies this increase in tank capacitance is not serious, because the ratio of the tuning capacitance to the tube output capacitance is reasonably high. Thus, the tuning capacitor may be adjusted slightly to compensate for the tube output capacitance. At the higher frequencies, however, this capacitance ratio decreases and it may not be possible to reduce tuning capacitance sufficiently to obtain resonance within the band.

Plate load. A survey of popular power tubes used by amateurs reveals that most of them have plate load resistances in the range between 2500 and 5000 ohms. The Nomograph can be used for all popular types because it covers resistance values from 1000 to 5000 ohms. If the selected tube has a plate load resistance in excess of 5000 ohms, parallel operation of two or more lower-power tubes should be considered. The plate load resistance may also be reduced by operating the tube at a lower plate voltage and a higher plate current.

Driving power. The power output from the driver stage should be at least twice the grid driving power required by the driven tube. When sufficient driving power is available, the selection of a triode greatly simplifies circuit design because triodes in general have low output capacitances, are easy to neutralize, and have a plate load resistance of approximately 3500 ohms. In addition, grid-No. 2 and grid-No. 3 considerations are eliminated.

Typical Design Problem

The following sample design problem can easily be solved with the aid of the Nomograph, charts, and curves.

Problem: To design a 500-watt input class-C amplifier for CW telegraphy service, having a single-ended, balanced, plate tank circuit and a tuned grid-input circuit, for operation on 40 meters. Power output from an available driver stage is about 10 watts.

Procedure: Refer to a technical booklet such as the "RCA Headliners for Hams" (Form No. HAM 103B), which lists popular RCA types for amateur use. With the aid of such a publication, we find that a beam power tube or a pentode (for example, type 813) fits the driving-power requirements for the plate input involved.

Having selected an RCA-813 as the desired tube (step 1), we next choose our circuit (step 2). Because the driver stage is on a separate chassis, link coupling is desirable. Consequently, the circuit of Figure 1B is chosen.

3. The power input is 500 watts under the following typical ICAS conditions given in the tube data:

DC Plate Voltage	2250	volts
DC Grid-No. 3 Voltage	0	volts
DC Grid-No. 2 Voltage	400	volts
DC Grid-No. 1 Voltage	−155	volts
Peak RF Grid-No. 1 Voltage	275	volts
DC Plate Current	220	ma
DC Grid-No. 2 Current	40	ma
DC Grid-No. 1 Current (Approx.)	15	ma
Driving Power (Approx.)	4.0	watts
Power Output (Approx.)	375	watts

4. The peak plate voltage is 1910 volts (2250 x 0.85).

5. The plate load resistance, obtained from the Nomograph, is about 4900 ohms.

6. Also from the Nomograph, the reactances X_C and X_L required for a plate load of 4900 ohms at 40 meters are 800 ohms for each section of the plate tank, and 400 ohms for the grid tank.

7a. Figure 3 shows that: (1) The capacitance of *each section* (C_P) of the split-stator plate-tank capacitor is 27 $\mu\mu$f at the mid-frequency. A capacitor of 50 $\mu\mu$f (each section) should be used to provide adequate band coverage. (2) The inductance of *each section* of the plate-tank inductor is 17 μh.

7b. Figure 4 shows that: (1) The capacitance of the grid-tank capacitor is 55 $\mu\mu$f

at the mid-frequency. A capacitor of 100 $\mu\mu$f should be used to provide band coverage. (2) The inductance of the grid-tank inductor is 8.9 μh.

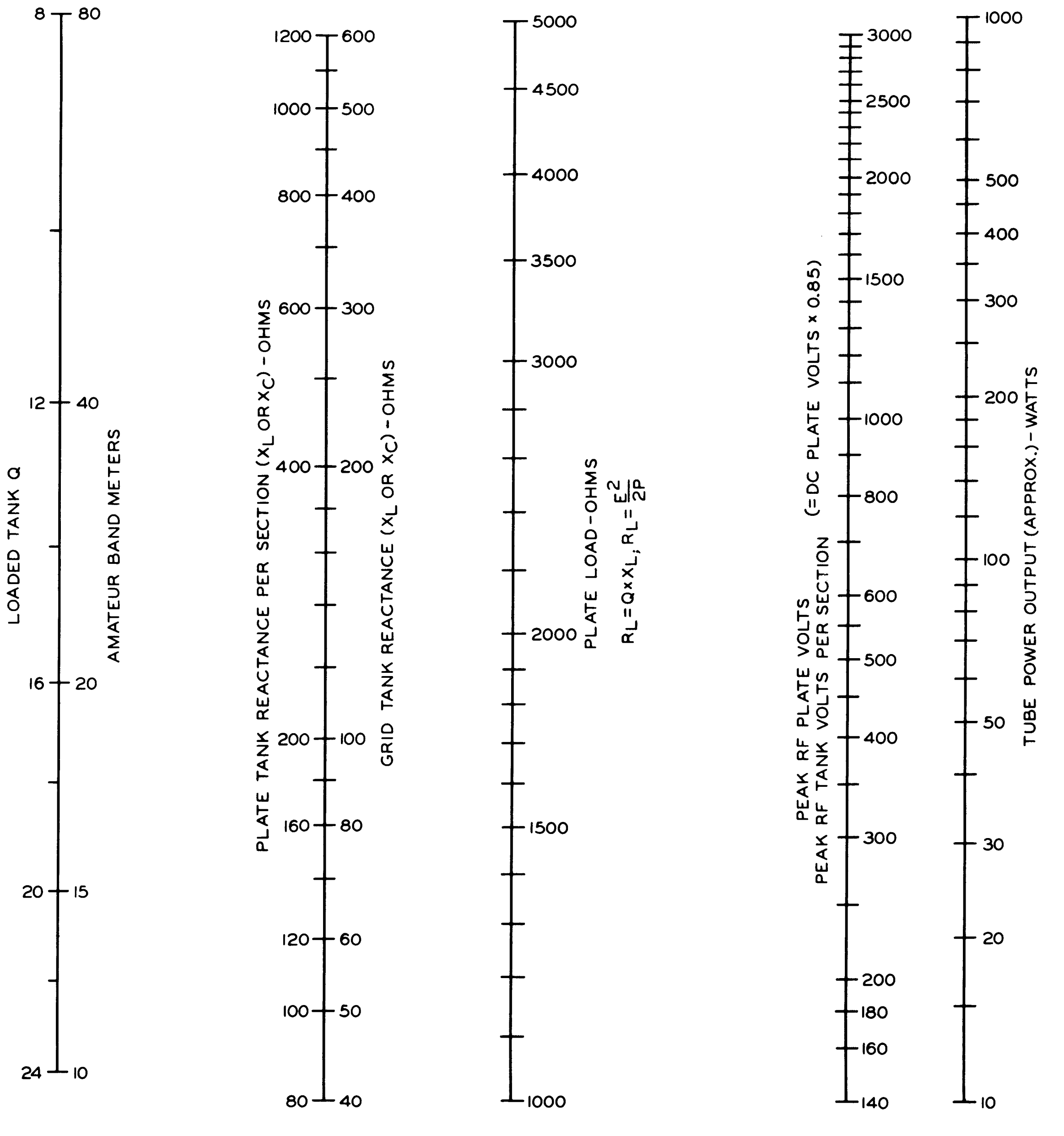
8 a. Figure 8 shows that rotor-to-stator spacing for each section (C_P) of plate-tank capacitor for a peak rf plate voltage of 1910 v = 0.06″, minimum. (For telephony service, the peak rf plate voltage is 2 x 1910 v = 3820 v, and the spacing would be increased to 2 x 0.06″ = 0.12″, minimum.)

8 b. Figure 8 also shows that rotor-to-stator spacing of grid-tank capacitor (C_G) for a peak rf grid voltage of 275 v = 0.01″, minimum distance (approximately).

9a. Step 7a showed that the plate tank inductance required is 17μh for each section, or a total inductance of 34 μh. Referring to Figure 5, we find curves for 1-inch, 2-inch, and 3-inch diameter coils. The table of wire-sizes shows that No. 10 wire is suitable for a tank coil used in conjunction with a tube having a 375-watt power output.

The Wire Table in Figure 5 shows that the maximum number of turns per inch for No. 10 wire is 9 turns. Referring next to the curves in Figure 5 (for three representative coil-form dimensions), we find that an inductance of

Figure 2. Nomograph.



34 μh requires 56 turns on a form having a 1″ diameter and a 2″ length, 41 turns on a form of 2″ diameter and 4″ length, and 32 turns on a form 3″ in diameter and 6″ in length. However, we have already noted that no more than 9 turns per inch can be wound with No. 10 wire, so it is clear that the coil form of 3″ diameter and 6″ length is the only one of the three which allows the necessary number of turns of No. 10 wire for an inductance of 34 μh. (For the experimenter willing to design coils using coil forms other than those used for the curves in Figure 5, the equation shown with the curves will be of value.)

9b. Step 7b showed that the grid-tank inductance required is 8.9 μh. Referring to Figure 5 again, with a tank inductance of 8.9 μh, and with #18 wire (suitable for power levels below 75 watts), we find that 30 turns on a 1-inch coil diameter and a 2-inch winding length provide the inductance required.

10. From the circuit shown in Figure 1B and from the "Miscellaneous Circuit Components Chart," Figure 6, we find that the following additional components, with indicated ratings, are required:

CAPACITORS

Capacitance	Working Voltage Volts (Minimum)	Type
Bypass:		
Filament, C_F		
0.001 to 0.01 μf	200	Disc Ceramic
Grid-No. 1, C_{G1}		
0.001 μf	200	Disc Ceramic
Grid-No. 2, C_{G2}		
0.001 to 0.005 μf	400	Disc Ceramic
Plate, C_B		
0.001 μf	2250	Mica
Neutralizing, C_N:		
0.5 $\mu\mu$f max.	4500	Variable-Air

RF CHOKES

Inductance mh	Current Rating Ma (Minimum)	Type
Plate:		
2.5	220	Any
Grid No. 1:		
2.5	15	Any

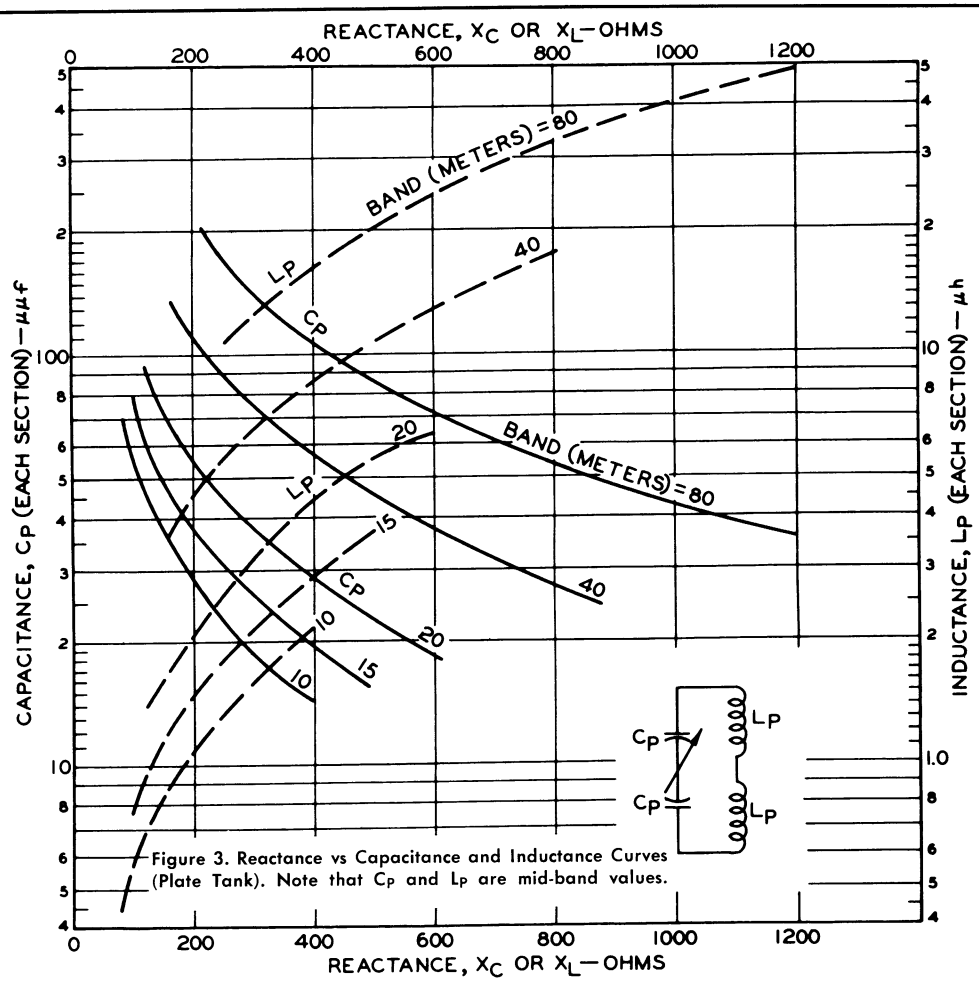


Figure 3. Reactance vs Capacitance and Inductance Curves (Plate Tank). Note that C_P and L_P are mid-band values.

That's all there is to it. You've designed a complete final stage, to the required specifications. If you're in a rush to get "on the air," you can stop reading right now and plug in your soldering iron. The balance of this article is a discussion of the various charts and tables, with some thoughts on plate tank circuits in general.

Basic Circuits

The circuits discussed in this article were selected for the following reasons:

1. They are very popular.
2. They are easily adjusted and require no special balancing. Neutralization is simple and straightforward.
3. All components can be easily obtained, and are available in great variety at relatively low cost.
4. There is less likelihood of TVI from single-ended balanced tank circuits than there is from the average push-pull amplifier.
5. A balanced tank circuit with link coupling allows easy installation of a low-pass filter designed to work on 50- or 75-ohm lines.

The Nomograph

The Nomograph (Figure 2) provides a simple method for solving a set of equations with reasonable accuracy. It indicates the proper plate load for any tube operating at a power level between 10 and 1000 watts and at dc plate voltage between 165 and 3500 volts. The Nomograph also relates "plate load" and "operating frequency" to the proper value of capacitive and inductive reactance required in the tank circuit. (It is important that the reactances X_C and X_L, along with loaded Q, be the specified values, to ensure proper plate loading and good circuit efficiency.) The Nomograph, used in conjunction with the single-ended balanced tank circuits shown in Figures 1A and 1B, also aids in the selection of a tube suitable for use with these circuits, as discussed under "Tube Selection."

To permit the use of practical values of tank C and L over the amateur bands from 80 through 10 meters, the Nomograph has been designed so that suggested values of loaded tank Q vary with the amateur band being used (Q increases with frequency).

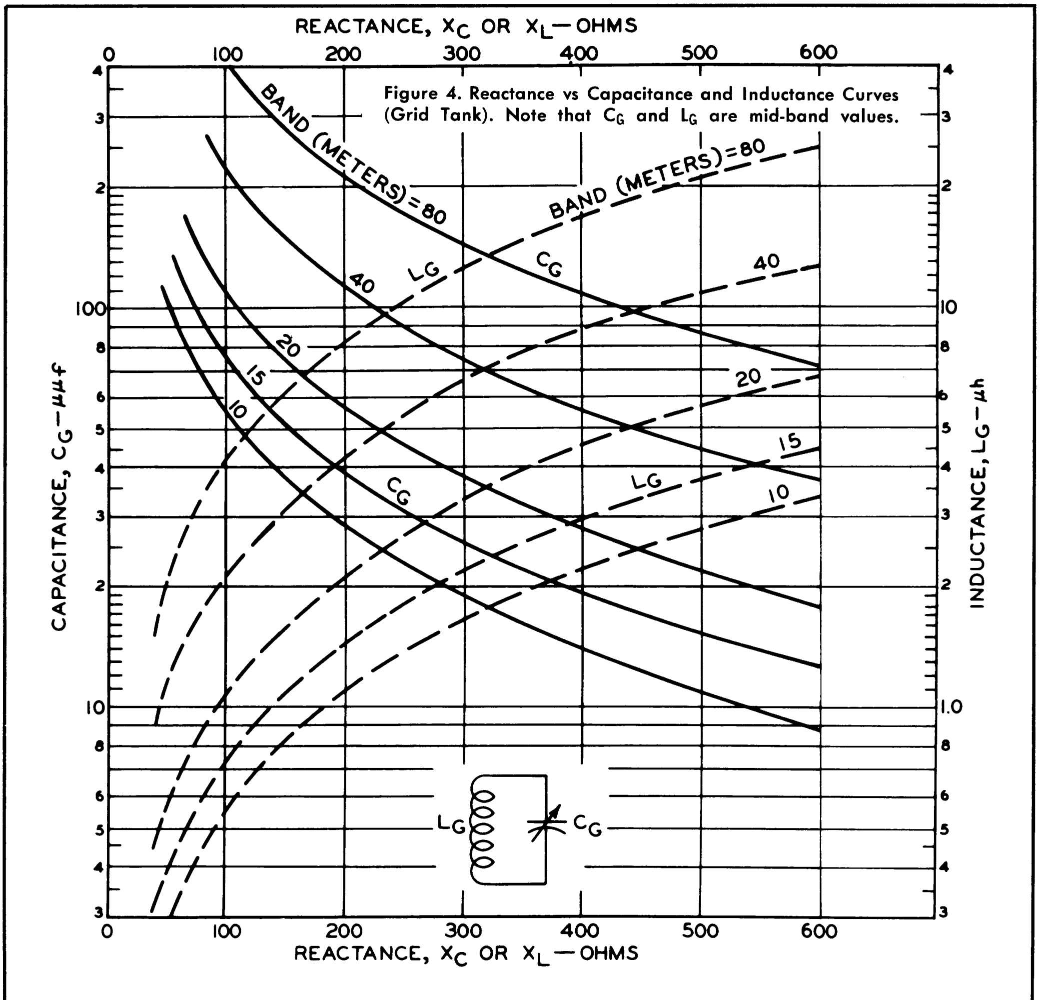


Figure 4. Reactance vs Capacitance and Inductance Curves (Grid Tank). Note that C_G and L_G are mid-band values.

Plate Tank Circuit Considerations

As mentioned in "Tube Selection," the minimum value of the tuning capacitor is an important consideration for operation at the higher frequencies. It is good engineering practice to select a capacitor having the lowest possible minimum capacitance because, whenever circuit constants are such that the tube output capacitance becomes a major consideration, a capacitor of low minimum value will allow more flexibility in the choice of the amplifier tube.

Regarding tuning-capacitor range, calculations show that, for tuning the amateur bands, the maximum percentage change in capacitance from the value at mid-frequency is approximately $\pm 15\%$. As a safety factor, a tuning capacitor having a minimum tuning range of $\pm 30\%$ should be adequate. Before testing a new amplifier, it is advisable to use a grid-dip oscillator to check the tuning range of each tank circuit with tubes in their sockets but no voltage applied.

Neutralization

Most class-C amplifiers must be neutralized in order to prevent self-oscillation. Triodes always require neutralization when used in the circuits shown in this article, whereas beam power tubes or pentode tube types may

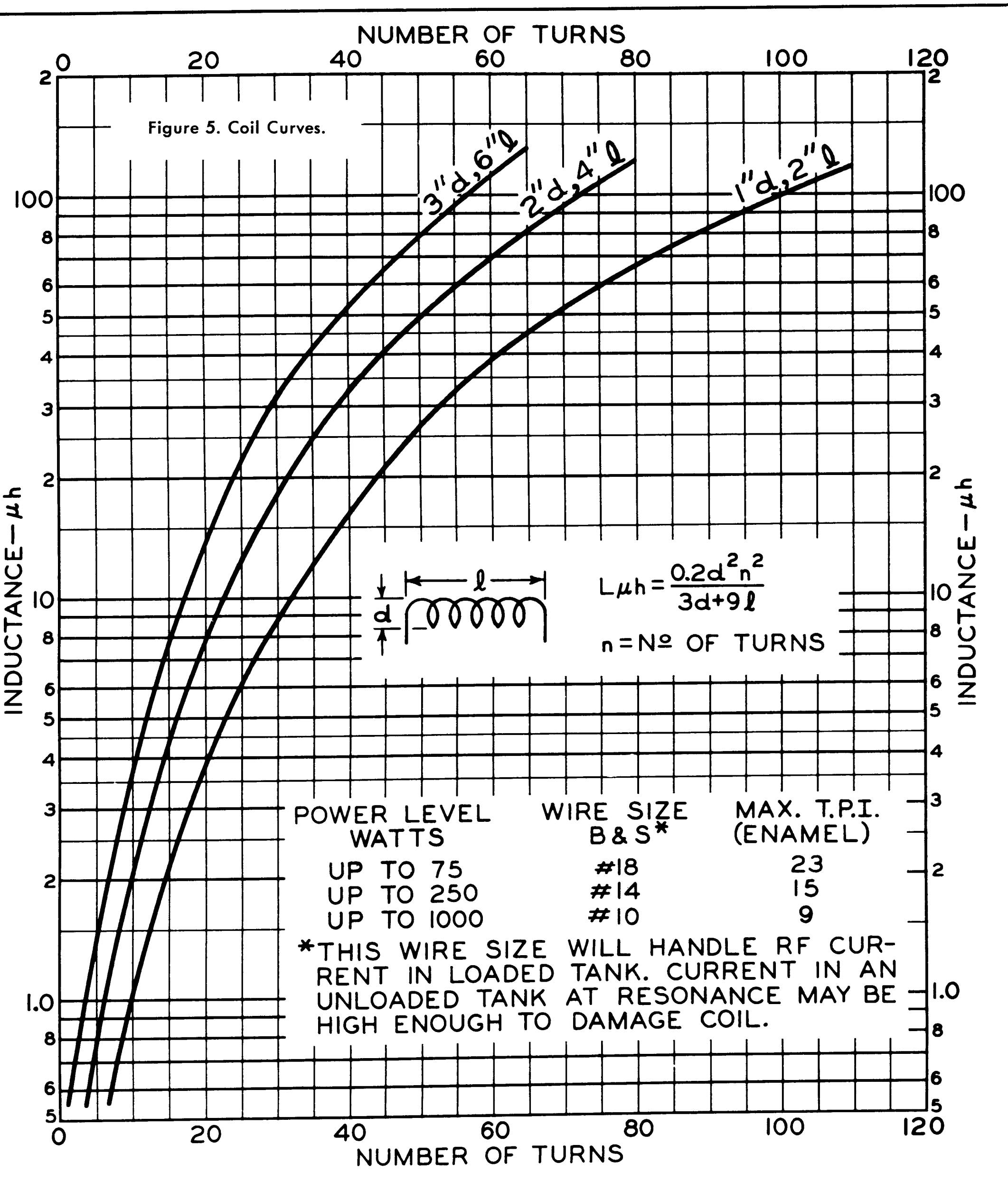


Figure 5. Coil Curves.

POWER LEVEL WATTS	WIRE SIZE B & S*	MAX. T.P.I. (ENAMEL)
UP TO 75	#18	23
UP TO 250	#14	15
UP TO 1000	#10	9

*THIS WIRE SIZE WILL HANDLE RF CURRENT IN LOADED TANK. CURRENT IN AN UNLOADED TANK AT RESONANCE MAY BE HIGH ENOUGH TO DAMAGE COIL.

require neutralization or may not.

When input and output circuits of beam power tubes or pentode tube types are effectively isolated and good bypassing is employed, it is generally not necessary to provide for neutralization. However, it is difficult to build such an amplifier and, therefore, many amateurs are confronted with the problem of a self-oscillating amplifier when a new final is tested. Because the inclusion of a small neutralizing capacitor during the building of a new amplifier is a comparatively simple task, the capacitor is a worthwhile addition in view of its contribution to stable operation.

Neutralizing capacitors required for beam power tubes and pentode tube types are usually on the order of ¼ $\mu\mu$f. If it should prove difficult to obtain a neutralizing capacitor of this low value, it is a simple matter to construct your own. The capacitor shown in Figure 7 is variable from about 1 $\mu\mu$f to 0.06 $\mu\mu$f, and will be adequate for most beam power tubes or pentodes. For those wishing to design their own neutralizing capacitor, the equation $A = 4.5\ Cd$ is suitable, where A is the area of one plate in square inches; C is in $\mu\mu$f (approximately twice the grid-No. 1-to-plate capacitance is an appropriate value); and d is the distance between plates in inches (see Figure 8 for minimum spacing).

Figure 6. Miscellaneous circuit-components chart.

CAPACITORS

Value	Minimum DC Working Voltage — Volts: Telegraphy	AM Telephony	Type
COUPLING, C_C			
0.0001 μf	E_{bb} of driver $+E_{g1}$ of driven stage	E_{bb} of driver $+E_{g1}$ of driven stage	Variable, air; or fixed mica
BYPASS:			
Filament, C_F 0.001—0.01 μf	200	200	Disc ceramic
Grid No. 1, C_{G1} 0.001 μf	E_{g1}	E_{g1}	Disc ceramic
Grid No. 2, C_{G2} 0.001—0.005 μf	E_{g2}	2 x E_{g2}	Disc ceramic
Plate, C_B 0.001 μf	E_{bb}	2 x E_{bb}	Disc ceramic
NEUTRALIZING, C_N 2 x Grid No. 1—plate capacitance (Max.)	2 x E_{bb}	4 x E_{bb}	Variable, air

RF CHOKES

Value	Current-carrying Capacity	Type
GRID 2.5 mh (Approx.)	At least I_{g1}	Any
PLATE 2.5 mh (Approx.)	At least I_p	Any

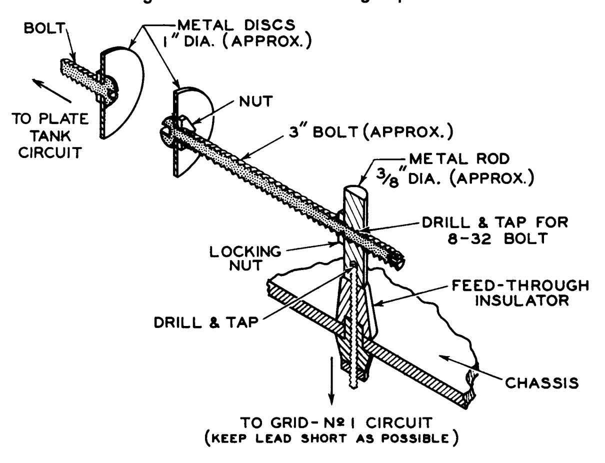


Figure 7. Small neutralizing capacitor.

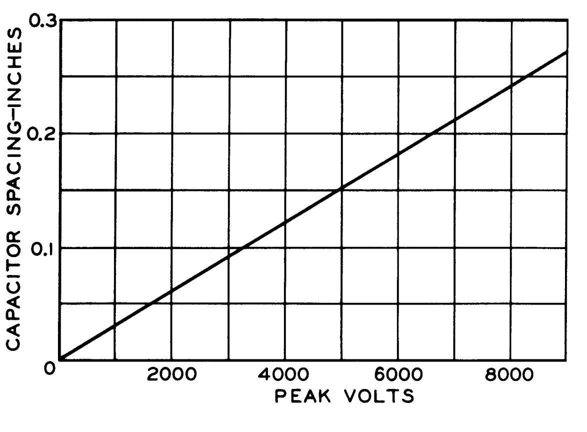


Figure 8. Capacitor-spacing Graph.

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Technical Editor

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HAM TIPS

RCA

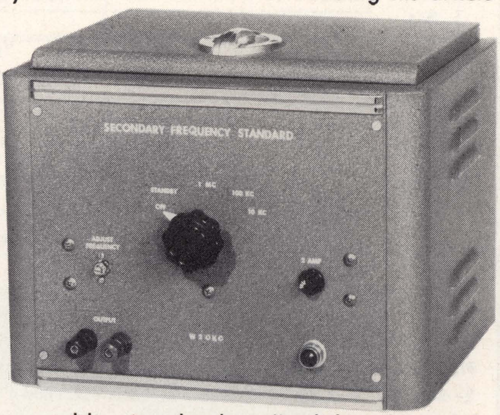
A PUBLICATION OF THE RCA TUBE DIVISION

Vol. XV, No. 4 December, 1955

A SECONDARY FREQUENCY STANDARD

By R. M. Mendelson, W2OKO
RCA Tube Division, Harrison, N. J.

W2OKO set out to design a frequency standard for ham use that would equal or surpass the performance of many commercial units. After reading his article most hams will be inclined to agree he has succeeded admirably. Here is a secondary frequency standard that can be built by the average ham with little difficulty and, more important, at low cost. It provides accurate and highly stable 10-Kc, 100-Kc, and 1-Mc markers, with the 1-Mc markers readable up to 250 Mc. In addition to marking the ends of amateur bands, it may be used for receiver calibration, for frequency measurement of received signals, for supplying an accurate, stable signal when "polishing" crystals, and as a signal generator for intermediate-frequency or front-end alignment.



"The licensee of an amateur station shall provide for measurement of the emitted carrier frequency . . . of sufficient accuracy to assure operation within the frequency band used." (FCC Regulation 12.135)

A versatile frequency standard providing 1-Mc harmonics readable to at least 250 Mc, 100-Kc harmonics readable to 150 Mc, and 10-Kc harmonics readable to 30 Mc is described in this article. The fifth harmonic of the 1-Mc oscillator may be set to within less than ½ cycle of the 5-Mc signal of WWV—the radio station of the National Bureau of Standards. This is an accuracy of better than one part in 10 million. And, if the instrument is allowed to warm up, its setting after 24 hours of operation in a room of fairly constant temperature will still be within 5 cycles of the 5-Mc signal of WWV—a drift of no more than one part per million. These figures may be more clearly appreciated when it is realized that the dials of the most expensive amateur communications receivers have divisions no smaller than 1 Kc, and are readable at best to 500 cycles.

The complete schematic diagram of the unit is shown in Figure 1. A cathode-coupled crystal oscillator circuit utilizing an RCA-12AT7 (V_1) operates at a fundamental frequency of 1 Mc. One triode section of V_1 operates as a cathode follower, the other triode section as a grounded-grid amplifier. The crystal and capacitor C_4 act as a series-

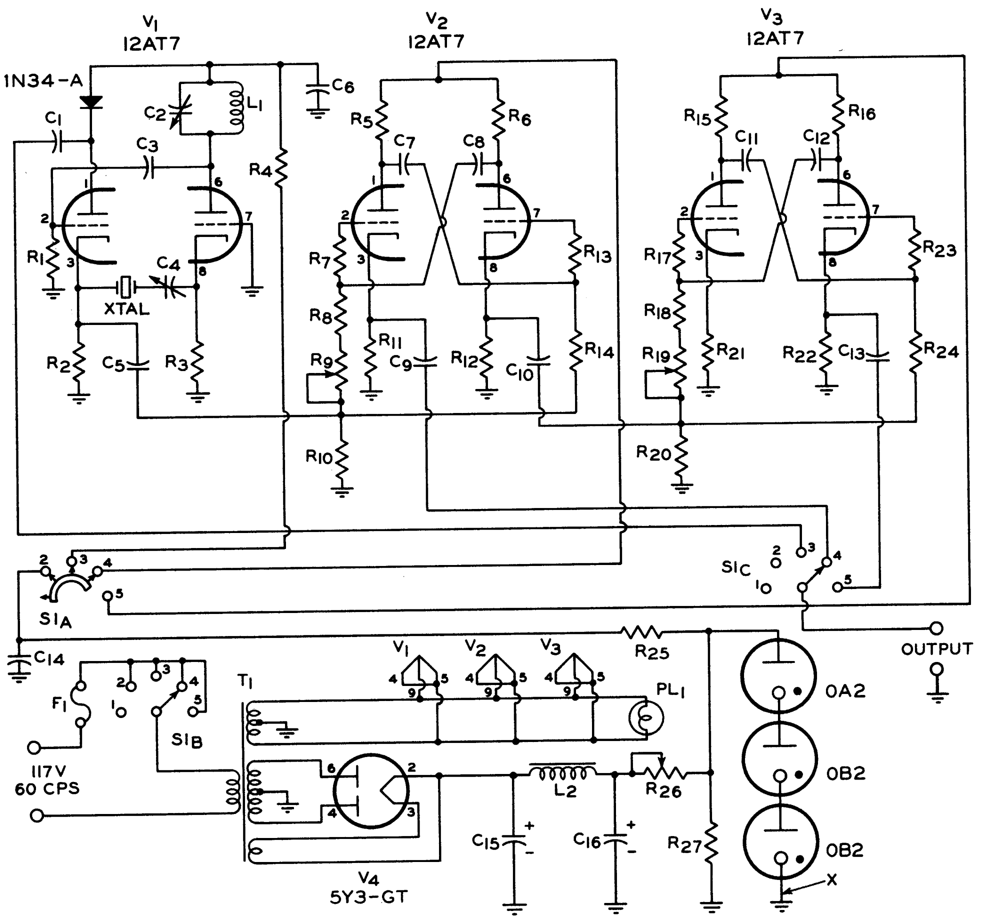


Figure 1. Schematic diagram and parts list. Positions of the three-pole ganged switch S1 are as follows: 1—Off; 2—Standby; 3—1 Mc; 4—100 Kc; 5—10Kc (S1 shown in 100-Kc position). S1 switches three circuits, but only two switch sections are needed because S1A and S1B are on opposite faces of same section.

C_1	15 $\mu\mu$f silver mica (Sangamo RR-1415).
$C_{2,4}$	50 $\mu\mu$f variable, with lock (Hammarlund APC-50C).
C_3	500 $\mu\mu$f silver mica (Sangamo RR-1350).
C_5	2000 $\mu\mu$f silver mica (Sangamo CR-1220).
C_6	2500 $\mu\mu$f mica (Elmenco CM-30).
$C_{7,8}$	270 $\mu\mu$f silver mica (Sangamo RR-1327).
C_9	100 $\mu\mu$f silver mica (Sangamo RR-1310).
$C_{10,13}$	1000 $\mu\mu$f silver mica (Sangamo RR-1210).
$C_{11,12}$	1500 $\mu\mu$f silver mica (Elmenco CM-30).
C_{14}	.01 μf ceramic (Erie GP-333).
$C_{15,16}$	40 μf, electrolytic, 500 WVDC (Mallory FP-288).
F_1	Fuse, 3 AG, 2 amp.
L_1	Plate tank inductance (Grayburne Varichoke V6). See text for modification.
L_2	Filter choke, 8 h, 85 ma (Stancor C1709).
PL_1	Pilot light, 6-8v (#40 or #47).
R_1	100,000 ohms ± 5%, 1 watt.
$R_{2,3,10,11}$, $R_{12,20,21,22}$	1,000 ohms ± 5%, 1 watt.
R_4	3,000 ohms ± 5%, 1 watt.
$R_{5,6}$	10,000 ohms ± 5%, 1 watt.
$R_{7,13}$	200 ohms ± 5%, 1 watt.
$R_{8,18}$	5,500 ohms ± 1%, 1 watt (Continental Carbon X1).
$R_{9,19}$	Potentiometers, 5,000 ohms (Clarostat 58-5000).
$R_{14,24}$	7,450 ohms ± 1%, 1 watt (Continental Carbon).
$R_{15,16}$	39,000 ohms ± 5%, 1 watt.
$R_{17,23}$	51 ohms ± 5%, 1 watt.
R_{25}	1,000 ohms ± 5%, wire-wound, 10 watts.
R_{26}	3,000 ohms wire-wound adjustable, 10 watts (Ohmite 1029).
R_{27}	82,000 ohms ± 5%, 1 watt.
S_1	3-pole, 5-position ceramic rotary switch (Centralab sections GG, R, and index assembly P121). See text for modification.
T_1	Power transformer, 320-0-320 v, 70 ma; 5 v, 2 amp; 6.3 v, 2.5 amp. (Stancor PC8408).
XTAL	Crystal, 1 Mc ± .0025%, hermetically sealed (International Crystal Manufacturing Co. FX-1).

Miscellaneous

Chassis	7" x 9" x 2", steel (Parmetal C-4511).
Cabinet with Panel	12¾" x 8" x 8½", steel (Parmetal CA-300).
Turret Sockets	9-pin (Vector type 6N9T). Three needed.
Crystal Socket	Ceramic (Millen 33302).
Binding Posts	(Superior 5-way). Two needed.

resonant circuit between the two cathodes. Because the crystal operates in a low-impedance circuit, it is affected only slightly by variations in tube or stray capacitance across it.

The fundamental frequency of the crystal oscillator circuit may be varied several hundred cycles by adjustment of C_4. This flexibility eliminates the need for a specially calibrated crystal and allows any well-designed hermetically sealed crystal to be used.

L_1 and C_2 form a circuit that is parallel-resonant at 1 Mc and serves as the plate-load impedance for the grounded-grid amplifier. C_3 provides feedback to the grid of the cathode follower. The RCA-IN34-A diode provides high harmonic content in the cathode-follower output.

V_2 and V_3, also RCA-12AT7's, are cathode-coupled multivibrators operating at 100 Kc and 10 Kc, respectively. V_2 is controlled by the injected 1-Mc signal from the crystal, and is synchronized at the proper sub-harmonic by adjustment of R_9. V_3 is controlled by the injected 100-Kc signal from V_2 and is synchronized at the proper sub-harmonic by adjustment of R_{19}.

The stability of this frequency standard is enhanced by voltage regulation of the power supply and by careful layout that keeps heat away from the crystal.

Construction

Although the oscillator is, in itself, very stable, its best performance can be obtained only with sturdy construction. Toward this end, turret sockets are used for the three frequency-generating stages. The terminal lugs on the turrets hold the small parts rigidly and minimize the effects of vibration or shock. To minimize rf losses, bus wire leads are used extensively. And finally, only "quality" parts are used. The advantage of a resistor or capacitor that will hold its value with age more than offsets the few cents extra in cost.

The placement of components has been carefully designed to keep heat sources away from the crystal and the one-megacycle tuned circuit, and it is suggested that the builder follow the layout illustrated in Figures 2 and 4.

Instead of the usual practice of fastening the chassis to the lower portion of the panel, this chassis is bolted to the panel about halfway up. This arrangement allows freer circulation of air within the cabinet, and at the same time yields a neater panel appearance. Two screws through the back of the cabinet support the chassis from the rear.

To provide a small, sturdy coil (L_1) for the 1-Mc tuned circuit, it was deemed best to use a commercial slug-tuned coil. However, the coil specified in the parts list had slightly too much inductance to resonate at 1 Mc in the circuit as built at W2OKO. Rather than pull turns off the heavily waxed coil, a small brass slug 11/16″ long by ¼″ in diameter (cut from an old potentiometer shaft) was used in place of the original iron slug in the coil form. The iron slug was removed and the brass one cemented into the open end of the coil form, flush with the end of the form. This brass slug lowered the inductance of L_1 sufficiently to allow it to resonate at 1 Mc with C_3 and the associated stray capacitance. [*The 1-Mc coil LS-3 manufactured by Cambridge Thermionic Corp. should resonate without modification in this circuit. Ed.*]

The other item to be modified is the ceramic switch. If the switch is assembled from the components specified in the parts list, it is

only necessary to hacksaw carefully through the shorting ring of the GG section, drill out one rivet and remove part of the ring, as shown in Figure 3. This modification provides single-knob control for application of high voltage to the proper tubes as the various output frequencies are selected.

Adjustment

After the wiring has been carefully checked, adjust R_{26} to about 2000 ohms, and insert a 50-ma meter in series with the string of voltage regulator tubes (at point X in Figure 1). Apply ac power by rotating the control knob to "Standby." After warm-up, note the current flowing through the regulator tubes. A value of 30 ma is desired. *Shut off the power* and adjust R_{26} accordingly. It will later be noted that as V_1, V_2, and finally V_3 are put into operation by the control switch, the regulator current will drop, due to current drain by these tubes. If 30 ma of regulator current flows during standby, there should still be a slight current flowing in the 10-Kc position, when all tubes are operating.

Loosely couple the frequency standard to a communications receiver. With capacitors C_2 and C_4 at mid-position, turn the control switch to the "1 Mc" position and locate a low harmonic signal at, for example, 2, 3, or 4 Mc. With the receiver beat-frequency oscillator turned off, adjust C_2 for a maximum reading on the receiver's S-meter. It should now be possible to detect clean, strong, signals at 1-Mc intervals up to well over 250 Mc.

To adjust the 100-kc multivibrator, set potentiometer R_9 to mid-position and tune the receiver to a band where continuous coverage of at least 1 Mc is available. It is now best to operate with the receiver bfo turned on. Locate and note two points on the dial 1 Mc apart by tuning in signals from the standard. Rotate the control switch to the 100-Kc range, and tune in one of the multivibrator harmonics between the 1-Mc markers. If R_9 happens to be set properly, the note should be clean; if the note is rough, adjust R_9 to give a steady, controlled signal. Then, starting at one of the previously noted 1-Mc marks, tune the receiver through the range to the other marker. Numbering the first 1-Mc marker as "1", there should be 11 markers up to and including the last 1-Mc marker note. If there are less, increase R_9; if more, decrease R_9 to obtain control at the correct sub-harmonic of 1 Mc. Repeat the process until the proper number of markers are counted. These should be clean signals, with no rough notes between. In this condition, signals should be heard in a good receiver to well over 150 Mc.

To adjust the 10-Kc multivibrator, set potentiometer R_{19} to mid-position and tune the receiver to a band where a continuous coverage of at least 100 Kc is available. As above, locate two end points—this time 100 Kc apart—and then rotate the control switch to the "10 Kc" position. Proceed as before. Tune in a signal between the 100-Kc markers, adjust R_{19} for a smooth note, then count the notes between the end markers. Adjust R_{19} for a count of 11 clean beats (including the end markers).

At this point, check that the voltage regulator tubes are still glowing. Although the glow should be faint, the current reading on the meter should be about 8 to 10 ma. If it is not, readjust R_{26}, *after shutting off the power*. The meter may now be removed from the circuit.

Before proceeding with the final adjustment of the crystal oscillator it is well to age the components for about 48 hours with the switch set for 10-Kc signals. After aging, check the multivibrators for proper synchronization. After this check, the frequency standard is ready for calibration against WWV.

The standard may be calibrated by matching the proper harmonic of its 1-Mc signal against either the 5-Mc or 10-Mc signal of WWV. It should be noted that there are a number of methods of frequency-matching more accurate than the system of eliminating an audible beat note. The method used at W2OKO was similar to that described on p. 462 of the 1955 ARRL *Radio Amateur's Handbook*. By this method (using the receiver bfo), the standard was set with ease to within less than ½ cycle of WWV's 5-Mc signal, as noted earlier in this article.

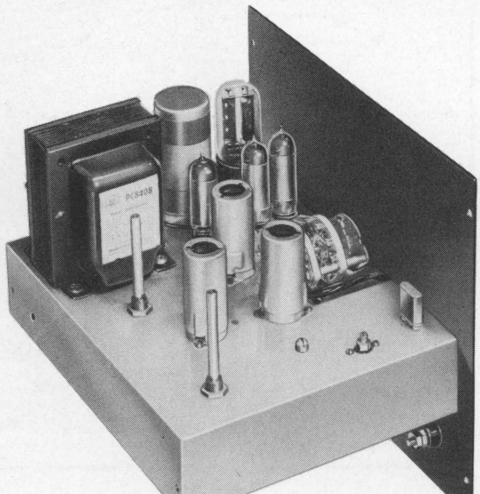


Figure 2. Top view of chassis. A portion of the chassis deck is cut away to clear switch S1.

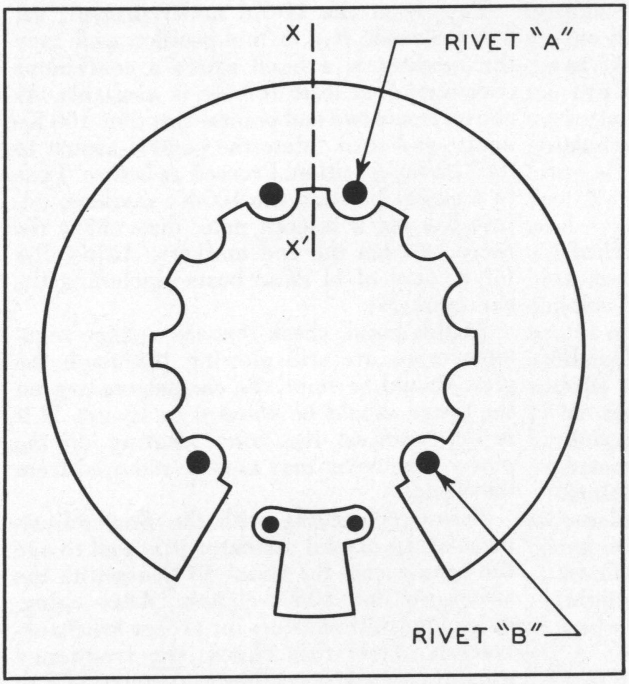
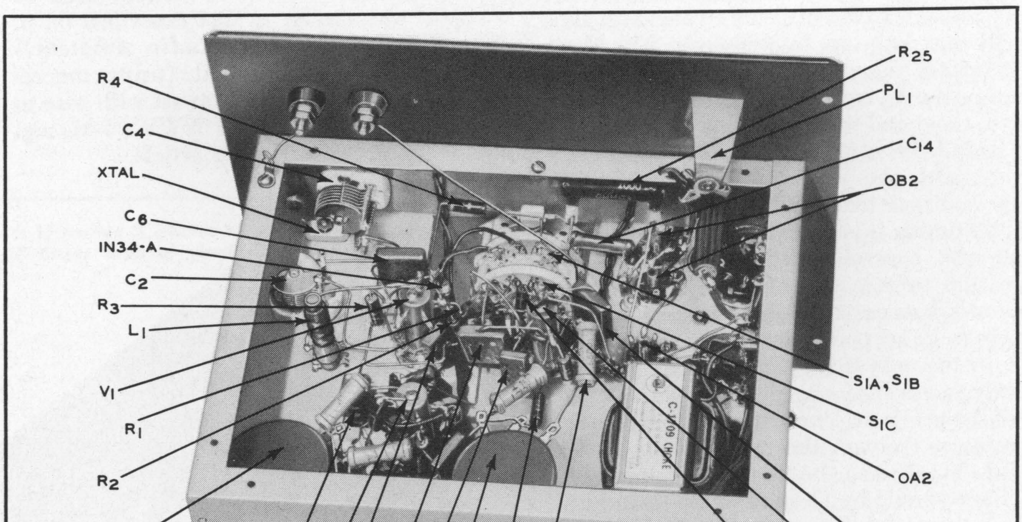


Figure 3. S1A face of switch section GG before modification. (S1B is on opposite face of this section.) Saw through switch plate along line X-X'. Drill rivet "A" until it is loose, but do not remove. Drill rivet "B" and remove. Remove portion of switch plate to right of line X-X'. Crimp rivet "A" tight again. (Rivet "A" helps secure S1B.)

Figure 4. Bottom view of chassis. Note brass slug mounted inside the coil form of L_1. The placement of components has been designed to keep heat sources away from the crystal and the 1-Mc tuned circuit (L_1, C_2); turret sockets allow neat, sturdy construction. It is suggested that the builder follow this layout as closely as possible.



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73 ...and happy hunting for '56

HAM TIPS

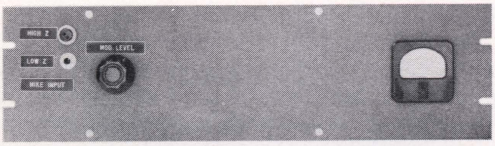
A PUBLICATION OF THE RCA TUBE DIVISION

Vol. XVI, No. 2 July-August, 1956

VERSATILE MODULATOR

by Peter Koustas, W2SGR

RCA Tube Division, Harrison, N. J.



The modulator described in this article can furnish any audio power between 25 and 100 watts and, therefore, can modulate 100% any rf input power up to 200 watts. Maximum power output is determined primarily by the plate voltage applied to the modulator tubes. No circuit changes are necessary when the power output level is changed other than in the connections to the proper taps on the modulation transformer.

The input circuit, which will accommodate any type of microphone, utilizes a transistor because of its low power consumption. The stability and low noise factor of the RCA-2N104 made it a logical choice for this application.

Circuit Description

A schematic diagram of the modulator is shown in Figure 1.

The transistor circuit given here is straightforward and not at all critical. The RCA-2N104 is a germanium alloy-junction transistor of the p-n-p type intended especially for small-signal audio applications. It is shown connected here in a common-emitter, base-input circuit. This method of transistor operation is analagous to common-cathode operation of a vacuum tube triode — with the base, emitter, and collector of the transistor corresponding to the grid, cathode, and plate, respectively, of the vacuum tube.

However, unlike the vacuum tube, which has a high input impedance at audio frequencies, the input impedance of the 2N104 in the circuit shown is approximately 1,000 ohms. Thus, low-impedance microphones (e.g.: carbon or dynamic types) may be used in this circuit without matching transformers. Crystal microphones, and other high-impedance types, do require a matching transformer in this circuit and one has been provided (T_1).

The RCA-12AT7 is a twin triode with two identical sections, each having a μ of 60. One section is used to provide a second stage of voltage gain; the other serves as the driver stage for the modulator tubes. In order to take advantage of the full gain afforded by the transistor, an impedance-matching, 3-to-1 step-up transformer is used between it and the input to the second stage. Modulation level is controlled by a 250,000-ohm potentiometer in the grid circuit of the first section of the 12AT7. Resistance coupling is used between the second and third stages of the modulator. Decoupling between stages is provided by R_{16} and C_9. Driver requirements are very modest, since no power is required to drive the modulator to full output. The second section of the 12AT7 develops adequate drive with no difficulty.

The outstanding features which make the RCA-6146 such a proven performer in rf service are the very reasons this versatile tube was chosen for the output stage of this modulator: high perveance and high power sensitivity. The high perveance of the 6146 allows this modulator to operate efficiently at low power levels with relatively low plate voltage. The high power sensitivity of the 6146 en-

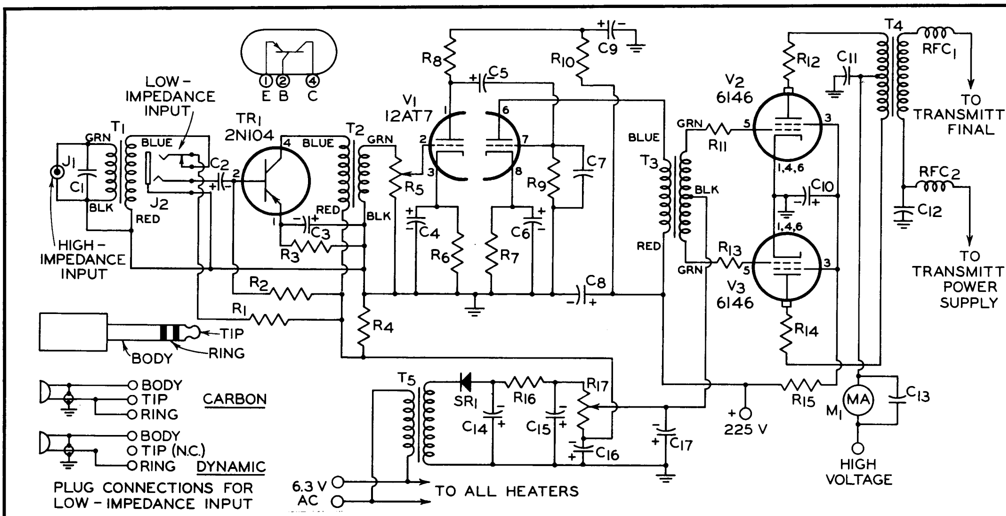


Figure 1. Schematic diagram and parts list.

C_1	500 $\mu\mu$f; mica	$R_{12,14}$	47 ohms, 1 watt
C_2	16 μf, 12 v; miniature	R_{15}	1,000 ohms, 1 watt
C_3	25 μf, 12 v; miniature	R_{16}	2,200 ohms, 2 watts
$C_{4,6}$	25 μf, 25 v	R_{17}	10,000 ohms, 25 watts; adjustable
C_5	.01 μf, 400 v	$RFC_{1,2}$	2.5 mh, 125 ma
C_7	.002 μf, 400 v	SR_1	Selenium rectifier, 65 ma (RCA-205G1, or equivalent)
$C_{8,9,10}$	8 μf, 450 v	T_1	Transistor input transformer, 200,000 ohms primary to 1,000 ohms secondary impedance (Argonne AR-100, or equivalent)
C_{11}	0.5 μf, 750 v	T_2	Interstage transformer, single plate to single grid, 1:3 turns ratio (Stancor A-53, or equivalent)
C_{12}	.005 μf, 1500 v; mica	T_3	Interstage transformer, single plate to push-pull grids; 10,000 ohms primary impedance, 1.5/1:1 primary-to-½ secondary ratio (Stancor A-4752, or equivalent)
C_{13}	0.1 μf, 600 v	T_4	Universal modulation transformer, 100-115 watts (UTC S-21, or equivalent)
$C_{14,15,16}$	20 μf, 150 v	T_5	Filament transformer, 6.3 v, 1 amp (Stancor P-6134, or equivalent)
C_{17}	8 μf, 150 v	TR_1	Transistor, RCA-2N104
J_1	Jack (Amphenol 80F, or equivalent)	V_1	RCA-12AT7
J_2	Jack, (Mallory 703B, or equivalent)	$V_{2,3}$	RCA-6146
M_1	Meter, 0-100 ma		
R_1	3,300 ohms, ½ watt		
R_2	220,000 ohms, ½ watt		
$R_{3,11,13}$	1,000 ohms, ½ watt		
R_4	470 ohms, ½ watt		
R_5	Potentiometer, 250,000 ohms		
R_6	2,200 ohms, ½ watt		
R_7	390 ohms, 1 watt		
$R_{8,9}$	270,000 ohms, ½ watt		
R_{10}	22,000 ohms, 1 watt		

ables this modulator to deliver full power output with negligible power required from the driver stage.

The 6146's are operated class AB_1 for all power levels up to a maximum of 100 watts. A driver transformer (T_4) which has a tapped primary is used to provide push-pull signal voltage for the output tubes. If sufficient gain is not available for a particular microphone when using the 1.5-to-1 tap, an additional tap on the primary can provide a primary-to-½ secondary ratio of one-to-one. Two 1,000-ohm resistors in series with the grid leads of the 6146's are used for the suppression of parasitic oscillations. The 47-ohm resistors in each plate lead serve the same purpose. Although these resistors are seldom necessary in audio equipment, it is always good practice to include them as a precautionary measure.

The modulation transformer that was selected can handle the maximum power output of the modulator. (The difference in price between a 60-watt transformer and this 115-watt transformer is less than five dollars). To determine the correct *secondary* impedance it is only necessary to divide the input voltage to the transmitter final by the normal operating current. The correct *primary* impedance will range from 2,500 to 7,500 ohms, depending upon operating voltage. Figure 2(b) is a plot of the *minimum* primary impedance required to prevent tube damage, versus operating plate voltage.

Figure 2(a) is a plot of output power versus plate voltage applied to the 6146's. To determine the required modulator plate voltage for a particular transmitter, divide the input power to the final stage of the transmitter by

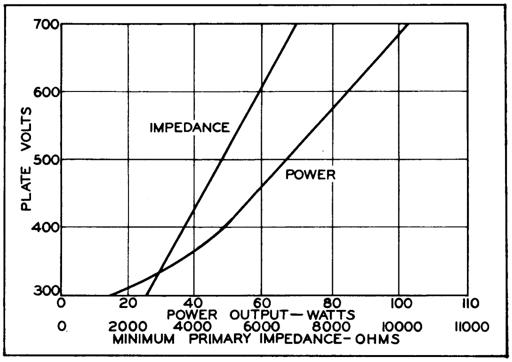


Figure 2. a) Power output vs plate voltage
b) Minimum primary impedance vs plate voltage

two, to get the audio power required for 100% modulation. Now find the minimum plate voltage required from Figure 2(a).

Higher plate voltages than those found from the above procedure may be used, and the modulation adjusted to the correct level by potentiometer R_5. In any event, R_5 should be used for fine adjustment of modulation level.

A few words of caution should be injected at this point. *Never* operate any modulator without having a load connected to the output. The high impedance of an unloaded transformer secondary reflected into the primary will cause abnormally high signal voltages to be generated and will almost always cause the insulation of the transformer to be punctured. Also, to prevent damage to the 6146's, never operate this modulator with the primary impedance of the output transformer below the value given in Figure 2(b) for the plate voltage being used.

Construction

Construction of the modulator is not difficult and requires only normal care in wiring. It is built on a standard aluminum chassis 5x13x3 inches deep and mounted on a rack panel 5¼x19 inches. This method of construction has two distinct advantages: a) a minimum of panel space is required; b) more complete shielding is obtained by utilizing the panel as the bottom cover of the chassis.

It is necessary to scrape the paint off the panel where the chassis comes in contact with it in order to insure a good rf bond between them.

The leads to the input jacks and gain control must be about five inches long, in order to allow assembly of the panel to the chassis after it is wired. It is therefore necessary to shield these leads to minimize any tendency towards stray hum and feed-back pickup. For maximum effectiveness, all parasitic-suppressing resistors must be mounted right at the tube socket, and directly on the plate cap.

Power Supplies

Two external voltage supplies are required by the modulator.

The first supply is for the plates of the 6146's. The voltage rating of this supply will depend on the modulation power output desired, as determined from Figure 2(a). Zero-signal drain on this supply will be between 50 and 60 ma. At 750 v, maximum-signal drain will be approximately 230 ma. The power supply should be capable of supplying maximum-signal current with good regulation.

The second external power supply must deliver approximately 50 ma at 225 volts. This supply powers the 12AT7 and the screen grids of the 6146's. It should never be turned on until after the plate supply has been turned on. Preferably, the supplies should be so wired that the plate supply must be on before the low-voltage supply can be energized.

Operating voltage for the transistor and bias for the modulator tubes are supplied by an internal supply. *This supply should be turned on before either of the above supplies.* Again, sequential switching to ensure the proper order of energizing the supplies is to be preferred. Transformer T_5 is a 6.3-volt filament transformer connected in reverse to obtain 115 volts from the 6.3-volt heater supply. A selenium rectifier and RC filter (R_{16}, C_{14}, and C_{15}), provide a negative voltage supply of —100 volts. Resistors R_1 and R_2 form a voltage divider between ground and the junction of R_{17} and R_4, which provides the 5 volts required to operate the transistor. Bias for the 6146's is adjusted by moving the tap of R_{17} to the appropriate point.

Operation

Other than usual precautions, there is no special procedure required to place the modulator in operation. The wiring should be thoroughly checked before any power is applied. With the tubes but not the transistor inserted, apply 6.3 v to the heater-voltage input terminals. The bias voltage at the grids of the 6146's should be set initially at maximum and then adjusted when all other voltages in the modulator are applied so that the zero-signal plate current as read on the meter is approximately 55 ma. Before insertion of the transistor, the voltage between ground and the junction of R_{17} and R_4 should be measured. If it is between 4.5 and 6 v, plug in

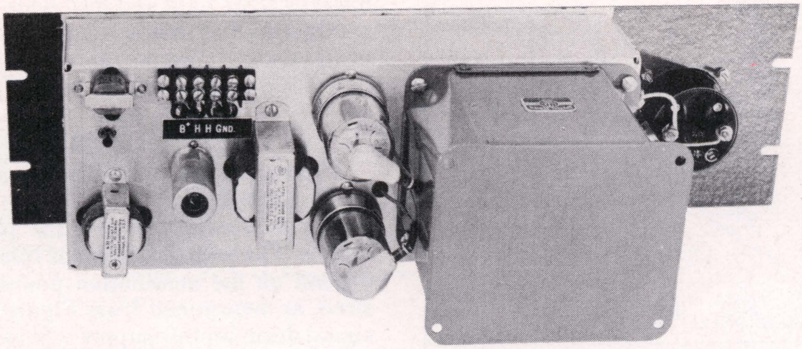


Figure 3. Rear view of modulator

the transistor. If the voltage at this point exceeds 6 v, a wiring mistake or a wrong value for R_4 may be the cause.

The modulator may be tested separately by using a resistor of the correct value as a load. The resistor used should have the same resistance as the impedance of the secondary taps to which it is connected and should be of sufficient power rating to withstand the output of the modulator. Power output may be measured by applying an input signal and measuring the signal output voltage across the resistor. The output power will be $\frac{(E_{rms})^2}{R}$. Again, a warning: in no case should the modulator be run without having a load connected to the secondary of the modulation transformer.

From your local RCA distributor, headquarters for RCA receiving and power tubes.

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HAM TIPS

A PUBLICATION OF THE RCA TUBE DIVISION

Vol. XVI, No. 3 September, 1956

THE MAKE-YOUR-OWN MICROPHONE

High Quality, High Output with a Transistorized Microphone

By G. D. Hanchett, W2YM

RCA Tube Division, Harrison, N. J.

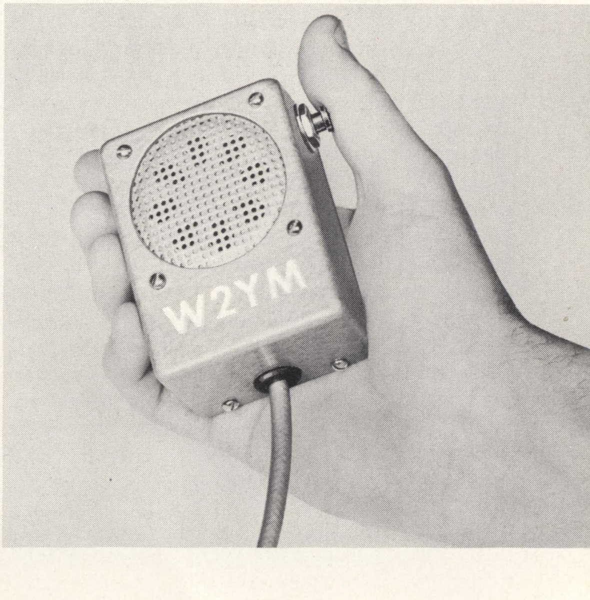
During the design of a mobile rig the author was recently confronted with the problem of finding a suitable microphone. A carbon microphone, although high in output, is noisy and of relatively uneven frequency response. A crystal microphone has good frequency response but is low in output and has the additional disadvantage – for mobile use especially – of temperature limitations.

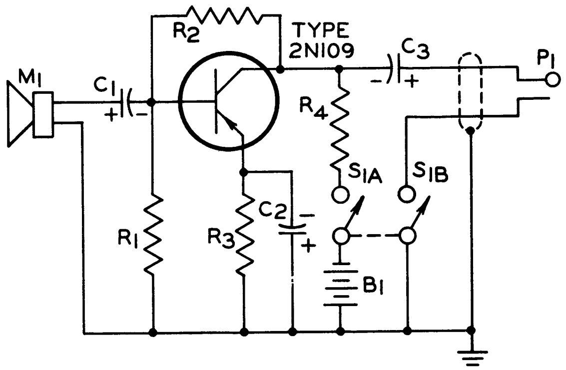
An attempt was made, therefore, to construct a microphone that would have good audio quality, be fairly high in signal output, be rugged enough for mobile ham use, be insensitive to unwanted electrical pickup, and still be within the price range of the average ham. This article describes the result; a surprisingly simple build-it-yourself microphone that meets all the given requirements.

Because of the abovementioned limitations of carbon and crystal microphones, they were discarded in favor of a dynamic "mike." The motor chosen for the microphone is the new RCA 239S1 2⅛" miniature PM speaker. The motor works into a one-stage, transistorized amplifier. Both motor and amplifier are contained in a small metal box that fits the hand comfortably.

The output of the microphone's built-in amplifier ranges between 0.75 v and 1.0 v measured across a load of 20,000 ohms or more. The audio quality of this microphone surpassed all expectations; in fact, for voice use it compared favorably with a so-called broadcast-quality crystal microphone. The total cost of the home-made "mike" (exclusive of the metal case, which was formed from sheet aluminum) was less than $10.00!

Figure 1 is a schematic diagram of the microphone. An RCA-2N109 p-n-p junction transistor is connected in a common-emitter, base-input amplifier circuit. Degeneration, provided through R_2, stabilizes the transistor against the effects of temperature variations. Push-button switch S_1 serves two functions: one pole (S_{1A}) energizes the transistor amplifier; the other pole (S_{1B}) can be used to control the transmitter.





B_1	Transistor battery, 9 v (RCA VS300, or equivalent).
$C_{1,2}$	50 μf, 12.5 v.
C_3	2.5 μf, 25 v.
M_1	Microphone, RCA 239S1 2⅛″ miniature PM speaker.
P_1	Male plug, 2-contact (Amphenol 80-MC2M, or equivalent).
R_1	10,000 ohms, ½-watt.
R_2	68,000 ohms, ½-watt.
R_3	1,200 ohms, ½-watt.
R_4	8,200 ohms, ½-watt.
S_1	Switch, push-button, double-pole single-throw, non-locking.
	RCA-2N109 Transistor.

Figure 1: Schematic diagram and parts list.

Construction

The microphone is assembled in an aluminum box 3″ L by 2¼″ W by 1½″ H. At W2YM the box was made by folding a sheet of aluminum cut to the proper pattern, welding the corners, and applying a coat of paint to the outside. If no welding equipment is available, the aluminum may be bent to form lips that may be bolted together. The box may also be formed from brass or copper, in which case the edges can be soldered together.

A 2-inch hole is cut in the front of the box to accommodate the 239S1 speaker. A piece of Reynolds "Do-It-Yourself" perforated aluminum is placed over the hole, inside the box, to serve as a protective screen for the speaker.

The transistor, its socket, and the associated small components for the amplifier were mounted on a strip of linenized bakelite. Any good insulating material, however, can be used for the mounting board. Even cardboard should be suitable.

The leads of the components are passed through #60 holes drilled through the mounting board. Where the leads come through the holes at the back of the mounting board they are bent into small hooks with a pair of long-nosed pliers. These hooks in the leads hold the components to the mounting board and also make for easy connection to the leads. Caution: be sure to observe polarity when connecting the capacitors.

The mounting board is held in place inside the box by two of the screws that fasten the speaker. These two screws should be long enough so that the mounting board can be held above the speaker by two ⅝″-long, ¼″-wide spacers.

If the transistor battery is placed in the position shown in Figure 3 before the mounting board is fastened into place, it should be found that the mounting board—when finally fastened down — will serve to hold the battery in place. It might be wise, however, to stick a small piece of insulating tape on the inside of the box near where the negative terminal of the battery will be located. This precaution will remove any chance of the battery accidentally shorting to the box.

The bass response of the microphone can be adjusted by damping the miniature speaker. To obtain suitable damping, cover nine holes in the rear housing of the 239S1 with felt. The felt may be held in place with ordinary household cement. The tenth and last hole in the rear of the housing should be covered with a piece of fiber or cardboard that has a 1/32″ hole drilled through for pressure release. Another pressure-release hole, this one ⅛″ in diameter, is drilled in the back cover plate of the microphone case. With this construction, the frequency response of the microphone is smooth through the range of 400 to 4,000 cps. Response, particularly at the low end, falls off rapidly beyond these limits — a desirable feature for a communications microphone.

Actual construction time for this microphone should be no more than a few hours. The author believes that the finished product is the best microphone for amateur communications now available. Try it and you'll agree.

The author wishes to thank J. Owens, W. Davies, F. Boryszewski, F. Wenzel, and J. Preston for their valuable aid or suggestions during the construction and testing of this microphone.

Figure 2: All components of the microphone and transistor amplifier. Note felt strips and fiber strip with small hole that are placed over the rear-housing holes of the speaker. Brackets to right of center are made from angle brass stock and are used to mount back cover on the case. One bracket has been cut away to clear grommet at bottom of case.

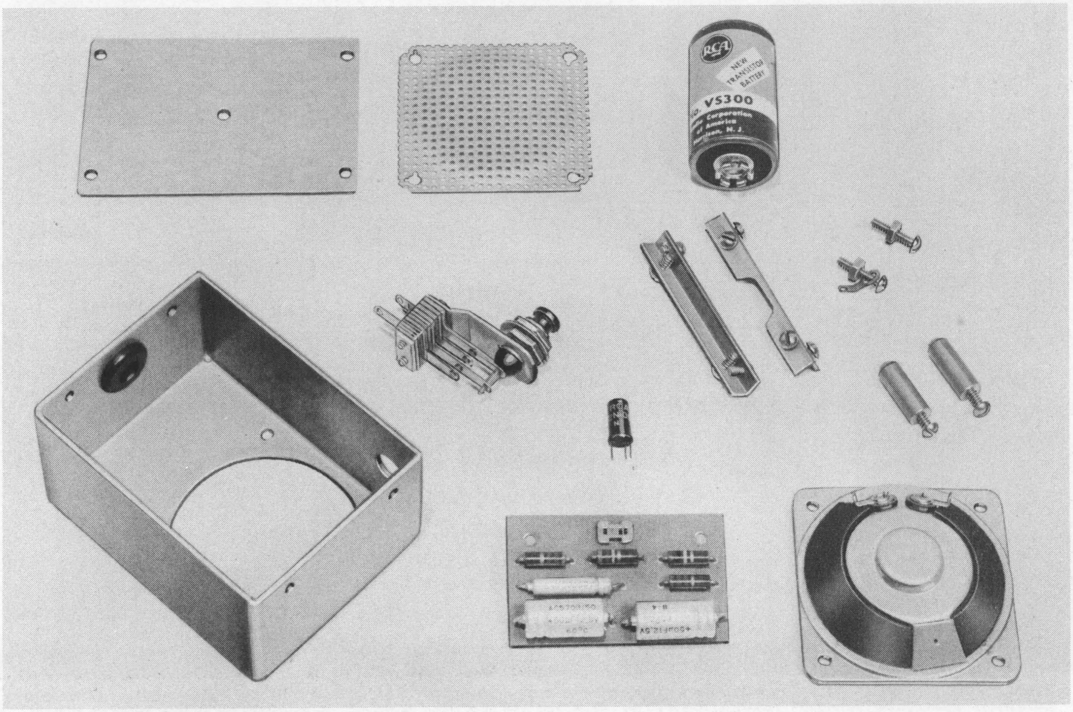
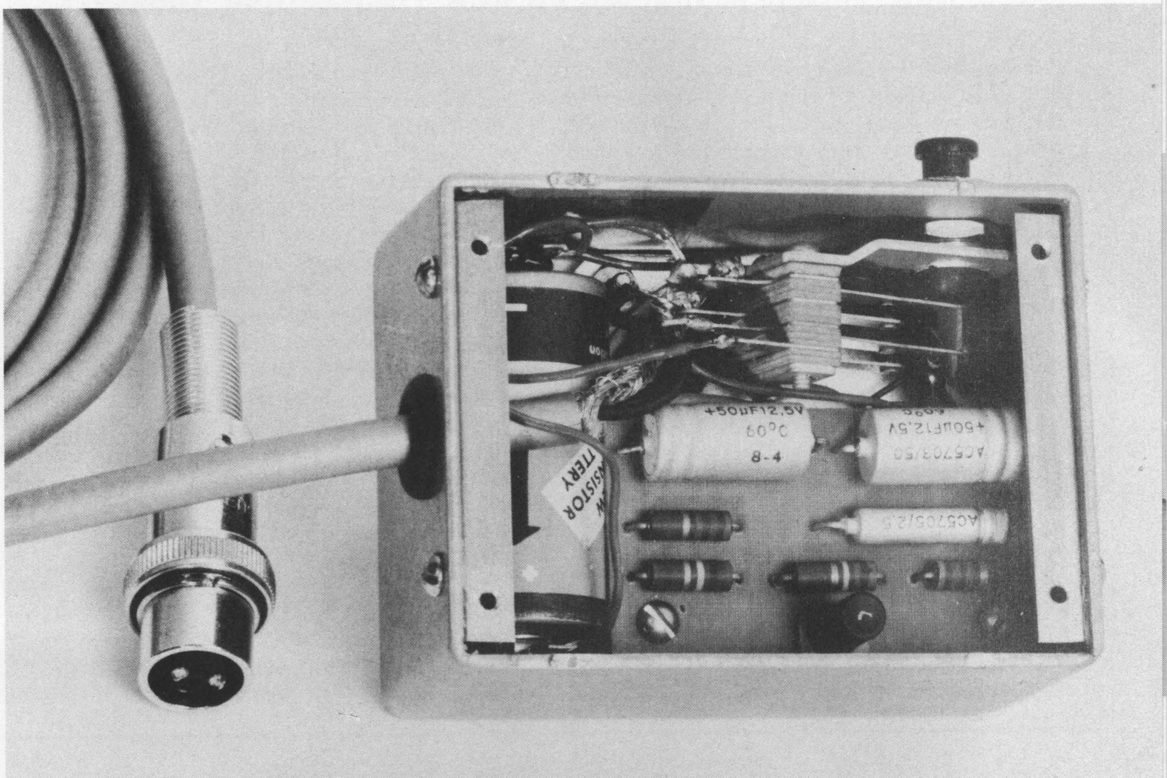


Figure 3: Microphone case with rear cover removed. The terminal board also holds the transistor battery in place.



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New Technical Manual on RCA Transmitting Tubes

Every ham will want a copy of *RCA Transmitting Tubes,* a 256-page manual published by the RCA Tube Division. A companion to the famous *RCA Receiving Tube Manual RC-17,* this new transmitting tube manual contains up-to-date comprehensive and authoritative technical data on 112 types of power tubes – including every "ham type" power tube in the RCA line, as well as tubes with plate-input ratings up to 4 Kw. Included in the manual are maximum ratings, operating values, characteristic curves, outline drawings, and socket-connection diagrams.

This manual contains 16 circuit diagrams showing the use of RCA tubes in representative transmitting and industrial applications. These circuits include a VFO for 3.5-4.0 Mc; crystal oscillators for both fundamental and harmonic output; amplifiers for Class C Telegraphy Service and for Class C Plate-Modulated Service; modulators; an electronic bias supply; transmitters for operation at 2 meters, 10 meters, and 462 Mc; and oscillators for dielectric and induction heating.

Covering basic theory of power tubes and their application in an easy-to-understand style, *RCA Transmitting Tubes* also contains valuable information for hams on generic tube types; tube installation and application; rectifier circuits and filters; interpretation of tube data; and the step-by-step design of af power amplifiers and modulators, rf power amplifiers, frequency multipliers, and oscillators. Simple calculations are given for determining proper operating conditions for tubes in class C telegraphy service, plate-modulated class C telephony service, frequency multipliers, and class AB and class B af amplifiers.

Rapid selection of an RCA power tube or rectifier tube for a specific application is facilitated by a series of five classification charts immediately preceding the tube-data section in the new manual.

A reference work that belongs in every ham shack, *RCA Transmitting Tubes* (Technical Manual TT4) may be obtained from your RCA tube distributor, or by sending $1.00 to Commercial Engineering, RCA Tube Division, 415 South 5th Street, Harrison, New Jersey.

HAM TIPS

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December, 1956

VISUALIZING SWR

'SWR Circle' Clarifies Mistaken Theories

By Morton Eisenberg*, W3DYL

Most amateurs have a working knowledge of Standing Wave Ratio (SWR) and are aware that it is preferable to have minimum SWR on feeders so that power lost in the antenna feeder is kept to a minimum. However, this writer has heard numerous remarks on the air which indicate that many theories exist on the subject of how the SWR can be varied, including the erroneous idea that SWR can be varied by changing the length of the feeder.

To help clear the air of such misinformation, this article contains a graphical presentation of the relationship between the SWR on a transmission line and the length of the line. The presentation, usually referred to as the "SWR Circle," shows how the feed-point impedance can be found when the SWR and electrical length of the transmission line are known.

The SWR on the transmission line between the transmitter and the antenna coupler, "A" in Figure 1, can be varied by tuning and adjusting the coupler by inserting a device such as an impedance bridge in the "A" line. In this manner, a "flat" or nonresonant line (SWR = 1.0) can easily be realized.

The SWR circle applies to the "B"-line. coupler to antenna or, if no coupler is used, transmitter to antenna. Although optimum tuning of the transmitter and coupler assures that the maximum rf power is being transferred to the feeder terminals, it has no effect on the SWR.

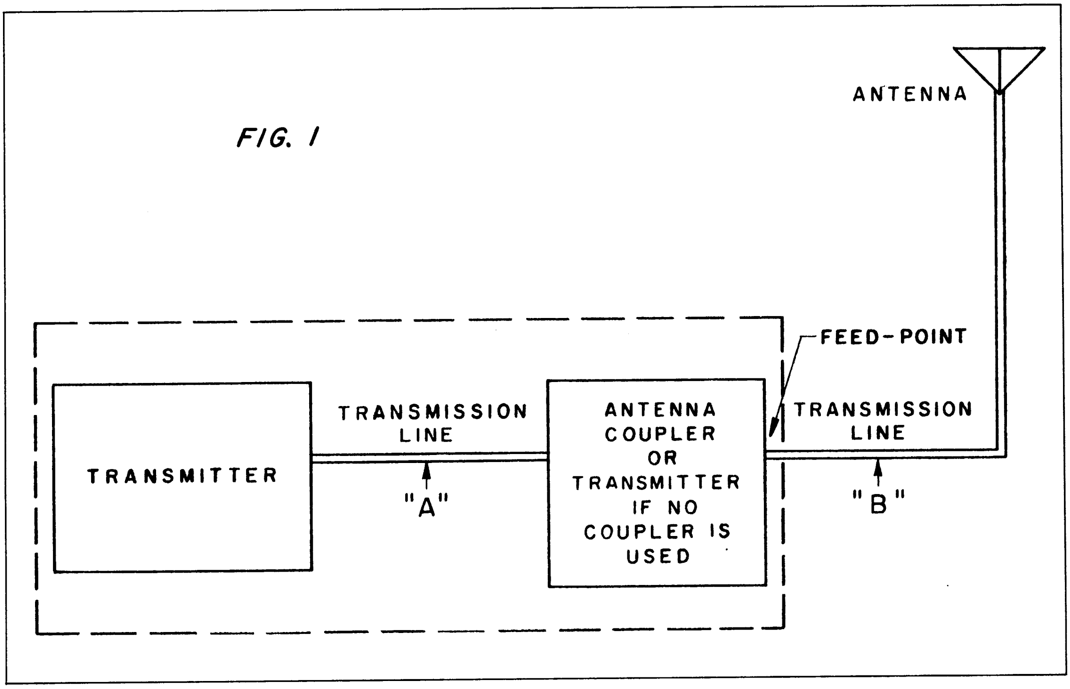
*Defense Electronic Products Division, Camden, N. J.

In Figure 2, the SWR circle is plotted for a 52-ohm cable. Similar SWR circles can be drawn for any other cable characteristic impedance and the procedure will be described later in this article.

Referring to Figure 2, suppose an SWR of 2:1 is measured on the "B"-line because a 52-ohm coaxial feeder is terminated by a 26-ohm resistive antenna impedance. Depending on the feeder length, the feed-point impedance could be 26 ohms resistive at Point X, 104 ohms resistive at Point Y, or any one of the infinite number of complex impedances, such as Point Z. Point Z represents a feed-point impedance of 65 ohms resistive in series with a 39-ohm inductive reactance. The convenient way to write this mathematically is: $65 + J39$.

Point X is the feed-point impedance which is found when there is no feeder, or when the feeder length is equal to a half-wavelength or any multiple of a half-wavelength. Point Y is the feed-point impedance when the feeder is equal to a quarter-wavelength or odd multiples of a quarter-wavelength. The feed-point impedance at Point Z is due to the feeder length being equal to one-eighth-wavelength.

It should now be clear that varying the length of the feeder cannot vary the SWR on the "B" line, nor can it vary the feeder losses per foot. When the feeder length is increased, simply "go around the SWR circle" in a clockwise direction. Remember that one full trip around the SWR Circle is equal to a half-wavelength of feeder.



The use of different feeder lengths to obtain variation in feed-point impedance is known to hams as "pruning the feeder to get the antenna to load." "Pruning the feeder" is sometimes necessary because of the limited impedance-matching capabilities of the coupling circuits. In this manner, a feed-point impedance which will more easily match the feeder to the transmitter (or coupler) can be obtained. *It is important to note* that although the feeder length has been changed, the SWR remains constant. You are simply going to another point on the SWR circle.

The SWR on transmission line "B" can be adjusted for minimum only by doing one of the following: (1) changing the transmitter frequency, (2) adjusting the length of the antenna element or elements, or (3) adding or adjusting a matching device at the junction of the antenna and the feeder.

Adjusting SWR for Receiver Feeders

The SWR situation on the receiver feeder is slightly different from the problems arising in transmitter feeders. In this case, the SWR is a result of a mismatch of the input impedance of the receiver and the characteristic impedance of the feeder. Consequently, the SWR can be adjusted to 1.0 by the use of a coupler at the input terminals of the receiver. This coupler is only necessary, of course, if the input impedance of the receiver is not equal to the characteristic impedance of the feeder.

Other SWR Circles

For various cable characteristic impedances, SWR circles can be drawn by the procedure in the following example:

To draw a circle where the SWR = 3:1, with a 300-ohm line, the circle would cut the 100-ohm point $\left(\frac{300}{3} = 100\right)$ and the 900-ohm point (300 x 3 = 900) on the horizontal axis. The center to be used for the compass would be $\frac{900 + 100}{2} = 500$. Setting the compass to a distance equivalent to $\frac{900 - 100}{2} = 400$ units, with 500 as the center, will complete the job.

The SWR circle is an extremely simple method of visualizing the effect of an antenna-to-line mismatch on the feed-point impedance. It is also an easy, more understandable way of showing that varying the feeder length is a futile way to minimize losses. The SWR (or the loss) remains unchanged. To accomplish a change in SWR (or to eliminate a line loss) for any specific frequency would require a climb up to your "sky-piece."

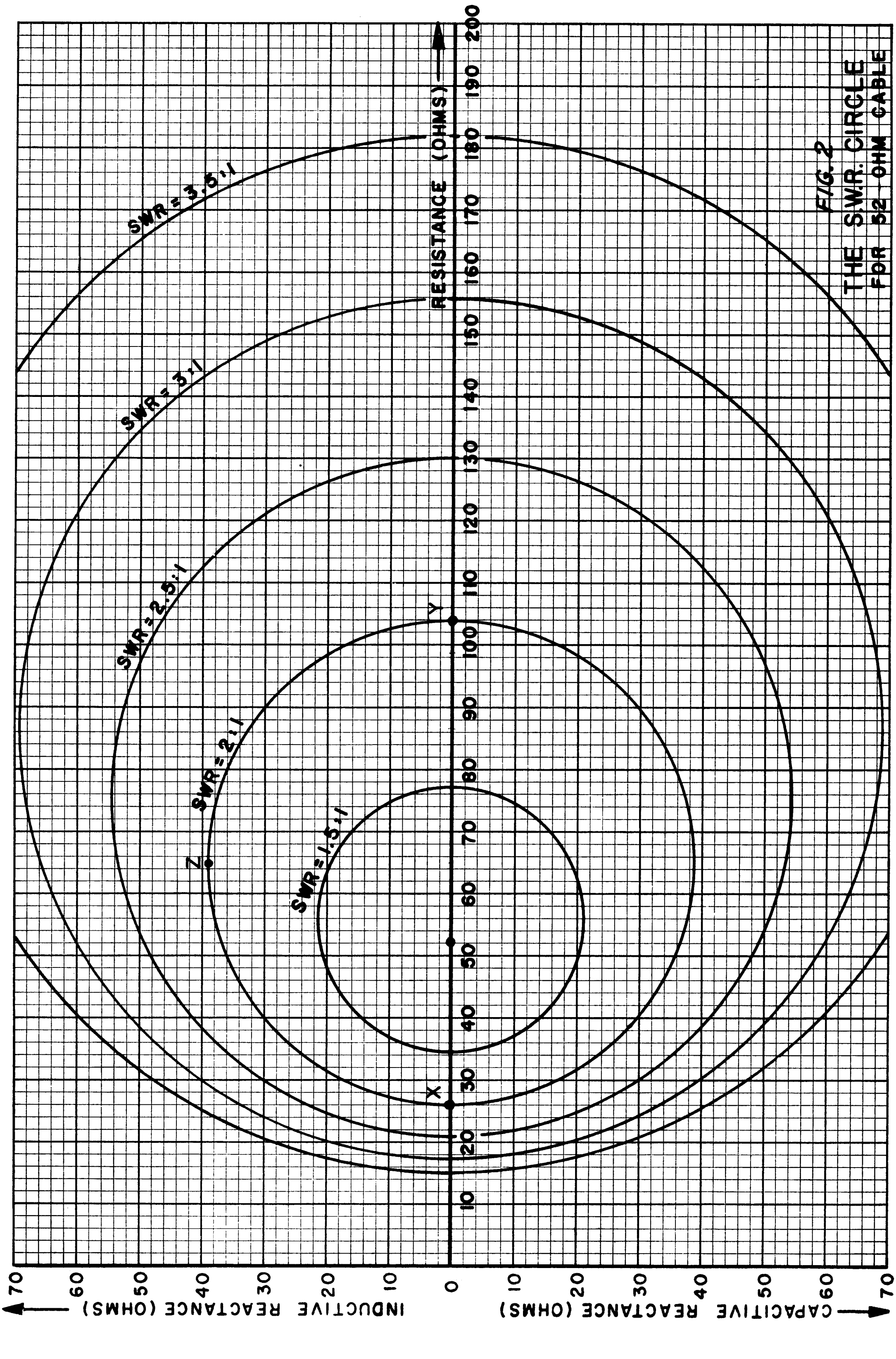


FIG. 2
THE S.W.R. CIRCLE
FOR 52 OHM CABLE

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